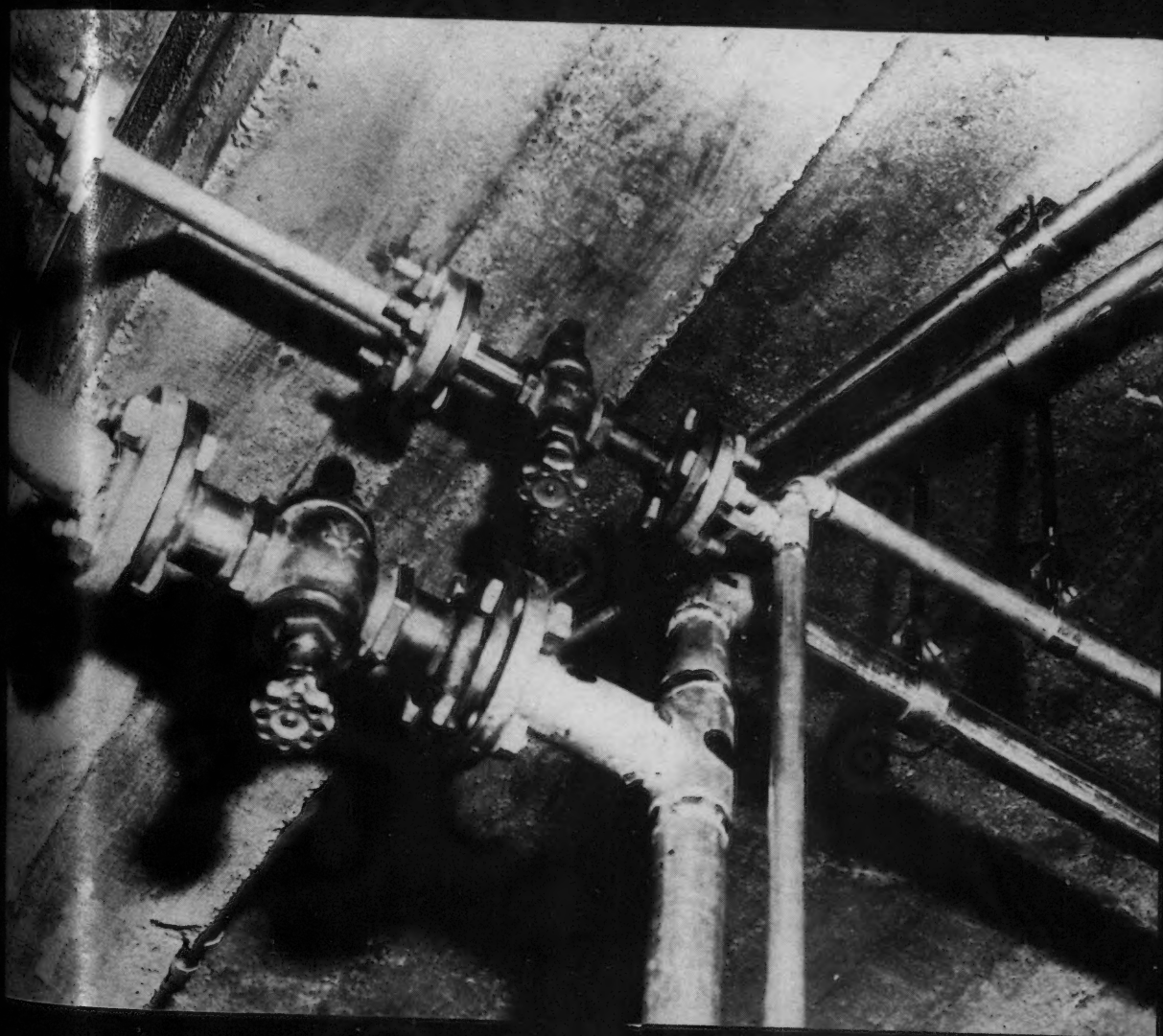



# *Corrosion*





**ORDINARY  
METHODS  
WON'T STOP  
CORROSION**

## **SPECIFY THE AMERCOAT METHOD— Designed to Give You PLUS PROTECTION**

Ordinary methods for controlling corrosion usually produce the ordinary results—rapid paint failure, costly replacements, product contamination, excess down-time, and hampered production. Halfway measures and the use of one or two general purpose coatings simply cannot provide adequate protection against corrosion's ceaseless attack.

Amercoat gives you a proven method of corrosion control, assuring you proper protection through these PLUS features:

- 1. Careful analysis** by a trained engineer of all the conditions present in each corrosion problem.
- 2. The ONE best recommendation** for the particular problem. AMERCOAT is a complete line of coatings, each formulated to solve or control specific corrosion problems.
- 3. On-the-job assistance** to your applicators and supervisors by a trained engineer. The AMERCOAT method ensures proper attention to surface preparation and application techniques for maximum protection.
- 4. Complete stocks** of fresh materials always near you at one of AMERCOAT's five regional warehouses or more

than 20 franchised distributor warehouses throughout the United States.

**5. Service based on experience.** The AMERCOAT method of corrosion control is the result of nearly 20 years' experience in solving or controlling corrosion problems in every major industry throughout the United States.

Write today for the name and address of the AMERCOAT representative in your area. At no obligation, he will gladly help you analyze your corrosion problems and evaluate your present control measures. If it is determined that you have a problem within our scope of experience, he will outline a complete program of AMERCOAT's PLUS protection for your plant or equipment.

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What type of pipe  
will give me the best  
service for the least cost?

How can I stop expensive  
pipe corrosion?

\* Where can I get impartial  
advice on the use of plastic  
vs. metal pipe?

CAN I GET LONGER LIFE  
BY USING PLASTIC PIPE?

Does plastic pipe  
really stop electrolysis,  
scaling and  
corrosion?

WILL PLASTIC PIPE WITHSTAND THE  
TEMPERATURES AND PRESSURES OF MY PLANT?

What type of  
plastic pipe is the  
best for my  
job?



## Three minutes spent on this REPUBLIC SUPPLY PIPE QUIZ

can help cut  
your maintenance costs!

If you'll take just three minutes to check these important points, you may discover a better, less expensive way to solve your own piping problems. It is to your advantage to keep informed regarding the latest improvements in piping materials.

### ✓ WHAT NEW TYPE OF PIPE MAY HANDLE YOUR JOB BETTER?

If you are not getting maximum trouble-free life from the pipe you are presently using, or if you are using expensive materials like lead, brass or stainless steel, you should investigate plastic pipe—it may save you money, and it's highly possible that plastic will outlive and outperform your present piping! Here's a simple formula for selecting the right piping material for your job:

$$\text{COST OF PIPE} + \text{INSTALLATION COST} + \text{MAINTENANCE COSTS} = \text{VALUE} \\ \text{LONGEVITY (YEARS OF LIFE)}$$

### ✓ WHY SHOULD I CONSIDER USING PLASTIC PIPE?

In the right application, plastic pipe can outperform any other pipe many times. You should consider the use of plastic pipe when: (1) corrosion (including electrolysis) is a problem; (2) plastic is less expensive than the piping materials presently being used; (3) you have scaling or wall caking; (4) ease of installing plastic pipe will result in worth-while savings; (5) light weight or flexibility is desired; (6) a higher flow factor is wanted (15-40% greater than steel).

### ✓ CAN I STOP EXPENSIVE PIPE CORROSION?

Scaling and pipe corrosion from any cause such as corrosive line fluids, electrolysis, soil condition, atmospheric conditions, tuberculation, etc. can be minimized and often

stopped completely by using plastic pipe. If you haven't looked into plastic for corrosive applications, you may be wasting thousands of dollars each year in shortened pipe life!

### ✓ CAN PLASTIC PIPES TAKE MY PRESSURES AND TEMPERATURES?

Unless you've evaluated your piping recently, and investigated the many new materials available, you may not be getting the maximum value from your present piping investment. Six basic types of plastic pipe now available provide a wide range of temperature and pressure applications. Working temperatures up to 230°F. and safe working pressures up to 300 psi are now possible with plastic pipe. Republic will help you determine the one best pipe for your particular job—whether it's plastic or metal.

### \* HOW TO GET IMPARTIAL ADVICE ON THE BEST PIPE FOR YOUR JOB.

Because Republic Supply handles all six basic types of plastic pipe—plus all types of metal piping, Republic is the only source able to give you impartial comparison of piping materials. Republic can recommend the one best type or kind of pipe for your particular piping problem, whether metal or plastic, and furnish it immediately from their complete warehouse stocks.

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serving Western Industry

- ☐ Please send special report showing comparative features, properties and prices of all types of plastic pipe.
- ☐ Please furnish free samples of plastic pipe.
  - ☐ Poly Vinyl Chloride
  - ☐ Polyethylene
  - ☐ Fiberglass
  - ☐ Tenite (Butyrate)
  - ☐ Styrene Copolymer (Uscolite)
  - ☐ Saran
- ☐ Please contact me regarding additional specific information on plastic piping.

Name.....

Firm.....

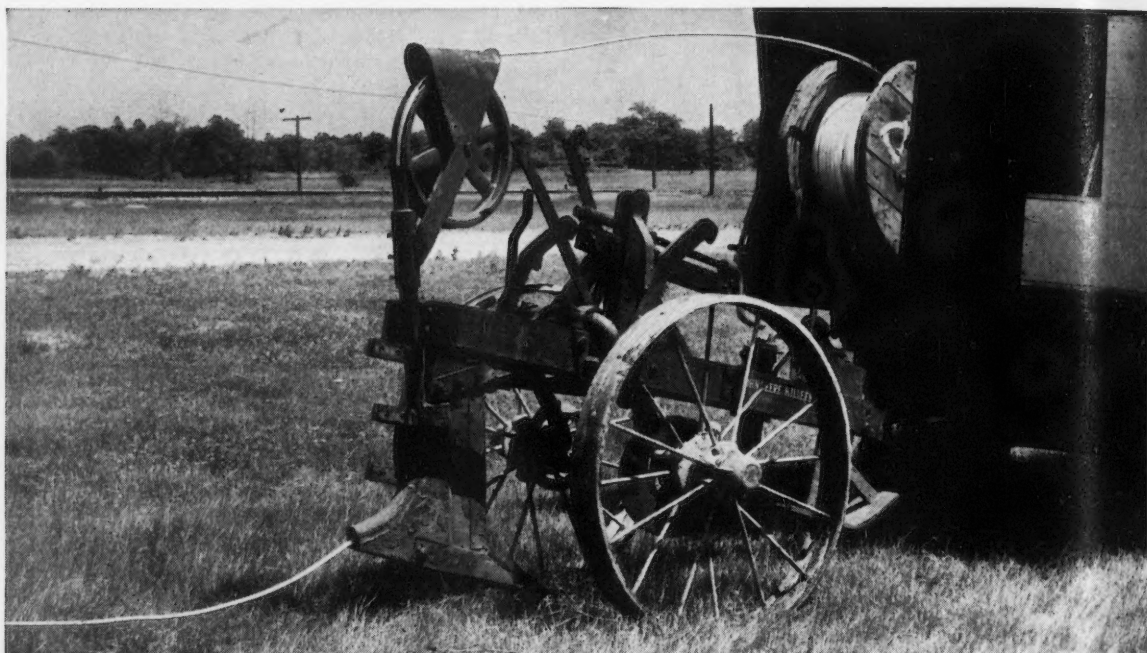
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# CUT THE COST OF PIPELINE PROTECTION WITH GALVO-LINE

Dow's Magnesium ribbon anode  
saves time and labor in installation



*Galvo-Line is installed by wire-laying plow drawn by truck or tractor.*

Has the high cost of anode installation discouraged you from using this most efficient method of pipeline protection? Then investigate Galvo-Line®, Dow's flexible cored, magnesium ribbon anode.

Time and labor are the big elements of cost in any anode installation. By providing a simplified method, these factors can be cut to the bone with Galvo-Line.

Up to *five miles of pipeline per day* can be protected by plowing in Galvo-Line. The installation is also simplified by the fact that the number of connections to the pipeline can be considerably reduced. Intervals of 500 to 1000 feet are generally adequate.

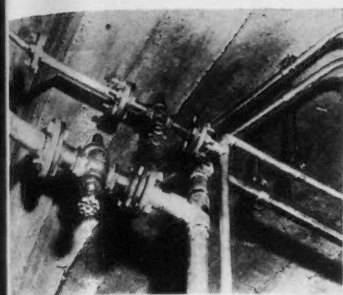
Galvo-Line cuts costs another way, too. It provides from three to seven times as much current per pound of magnesium installed as conventional magnesium anodes. More uniform distribution and efficient utilization of current make Galvo-Line both economical and dependable for pipeline protection.

When you plan your next protection program, figure it *two ways* . . . one with Galvo-Line. Let the facts prove themselves.

Call your nearest Dow office or Dow distributor for complete data. THE DOW CHEMICAL COMPANY, *Magnesium Department*, Midland, Michigan.

*you can depend on* **DOW MAGNESIUM ANODES**





THIS MONTH'S COVER—Shown here is an aluminum "sacrificial joint" (first light colored joint to the left of the upper valve), which is inserted between copper plumbing connections and aluminum piping in the new Alcoa Building recently completed at Pittsburgh. This joint is designed to absorb galvanic currents created by connection of dissimilar metals in the plumbing system. The joint can be replaced easily when consumed.



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**CORROSION**  
research and control



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## CONTENTS

	Page
Directory of NACE Regional and Sectional Officers	iv, v, vi
Directory of Technical Practices Committees	viii, ix
Officers and Directors, National Association of Corrosion Engineers	xiv

## TECHNICAL SECTION

	Page
Corrosion Instruments and Measurements Handbook Is Committee's Objective By H. N. Hayward	335
Fundamental Concepts of Electrode Potentials By Andre J. deBethune	336
Discussion: Lee H. Elizer, Page 343; Reply by A. J. deBethune, Page 343	
Resistance of Aluminum Alloys to Weathering By C. J. Walton, D. O. Sprowls and J. A. Nock, Jr.	345
Corrosion Resistance of Beryllium Copper—A Survey By John T. Richards	359
Interpretation and Significance of Potentials of Metals in Aqueous Solutions By Morris Cohen	372
Field Tests of Exterior Coating for a Pipe Line Conveying Fuel Oil Heated to 200 Degrees F By E. R. Stauffacher and R. R. Davidson	377
A Technical Note—Corrosive Attack by Acidic Decomposition Products Evolved by Paints When Drying	344

## DISCUSSIONS

Magnetic Amplifier Controls for Rectifier Protecting Underground Metallic Structures Cathodically by Oliver Henderson. Discussion by H. G. Sheard, Reply by Oliver Henderson, Page 382	
Corrosion by Aqueous Solutions at Elevated Temperatures and Pressures. By F. H. Beck and M. G. Fontana. Discussion by William G. Ashbaugh, Wm. E. Baker, Page 382; Werner O. Tunderman, John W. Weis, Robert F. Hausman, Page 383; Replies by F. H. Beck, Pages 382, 383.	
Corrosion of Casing in Oil and Gas Wells by Jack L. Battle. Discussion by Jack P. Barrett, Page 383.	
Some Notes on the Oxidation Resistance of Boron-Containing Chromium-Nickel-Cobalt-Iron Alloys by W. O. Binder and E. D. Weisert. Discussion by E. N. Skinner, Page 383; M. A. Scheil, Page 384; Replies by E. D. Weisert, Page 383; W. O. Binder, Page 384.	
Cable System Design for Cathodic Protection Rectifiers by Ray M. Wainwright. Discussion by William Dudley, S. P. Ewing; Reply by Ray M. Wainwright, Page 384.	

## NACE REGIONAL AND SECTIONAL NEWS

	Page		Page
Montreal, Portland, Ore. Sections Approved	3	San Francisco Section Hears	4
NACE Calendar	3	J. J. B. Rutherford	4
Philadelphia Section, ASTM Meeting Held	3	Interim Canadian Officers Confirmed	4
Million Dollar Savings on Oil Well	3	Whitney Talks at New York	4
Casing Damage Reported to Teche Section	3	Permian Basin Tour Schedule Is Given	5
N. Texas Section Hears B. B. Morton	3	Twelve Technical Committees to Meet at Tulsa	6
Cleveland Section Elects Palmquist	4	S. Central Region to Be Invited to Meet at Houston Again	13
Maitland Talks on Cables	4		

## GENERAL NEWS OF CORROSION INTEREST

	Page		Page
Topic of the Month—Visual Identification of Line Pipe By Hans Schmoldt	1	New TP-18A Officers	7
Activated Bauxite Used in Adsorption	2	Many Papers Committed for K. C. Program	8
Pending Short Courses Listed	3	Galvanized Steel Wire Adequate for Aluminum Alloys in Marine Environment	10
Short Course Postponed	3	Special Libraries Sessions	10
British Corrosion Group Holds 10 Meetings	5	U. Cal. at Berkeley Schedules Marine Corrosion Conference	11
October is Closing Date for Fulbright Awards	5	Houston University's Paint Course Started	11
28 Papers Listed on Non-Destructive Testing Society's Program	7	Wisconsin U. Schedules Short Course	11
		Book Reviews	14
		New Products	16

INDEX TO CORROSION ABSTRACTS	25
INDEX TO ADVERTISERS	60

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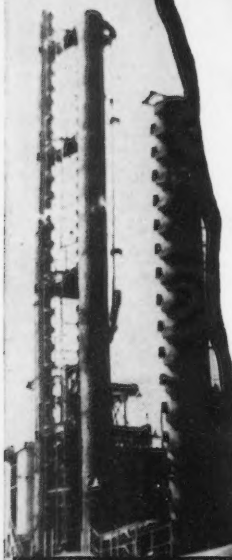
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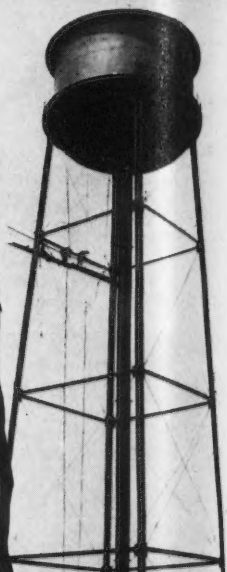
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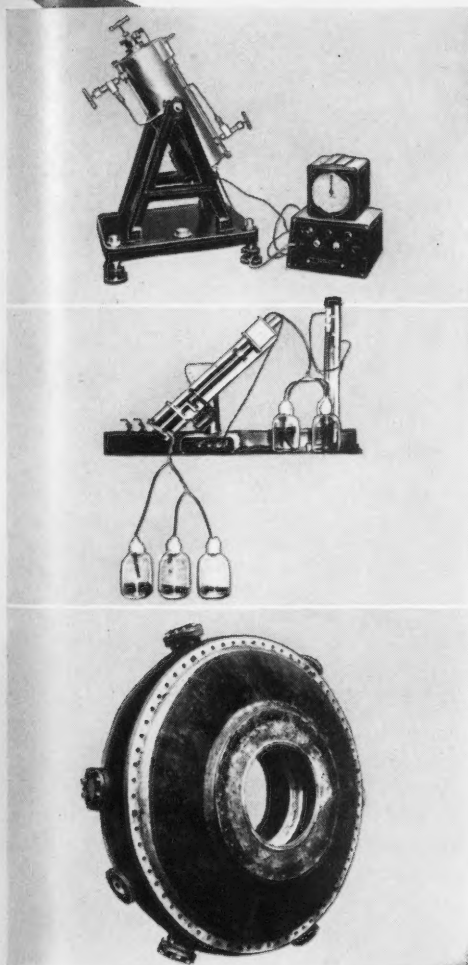


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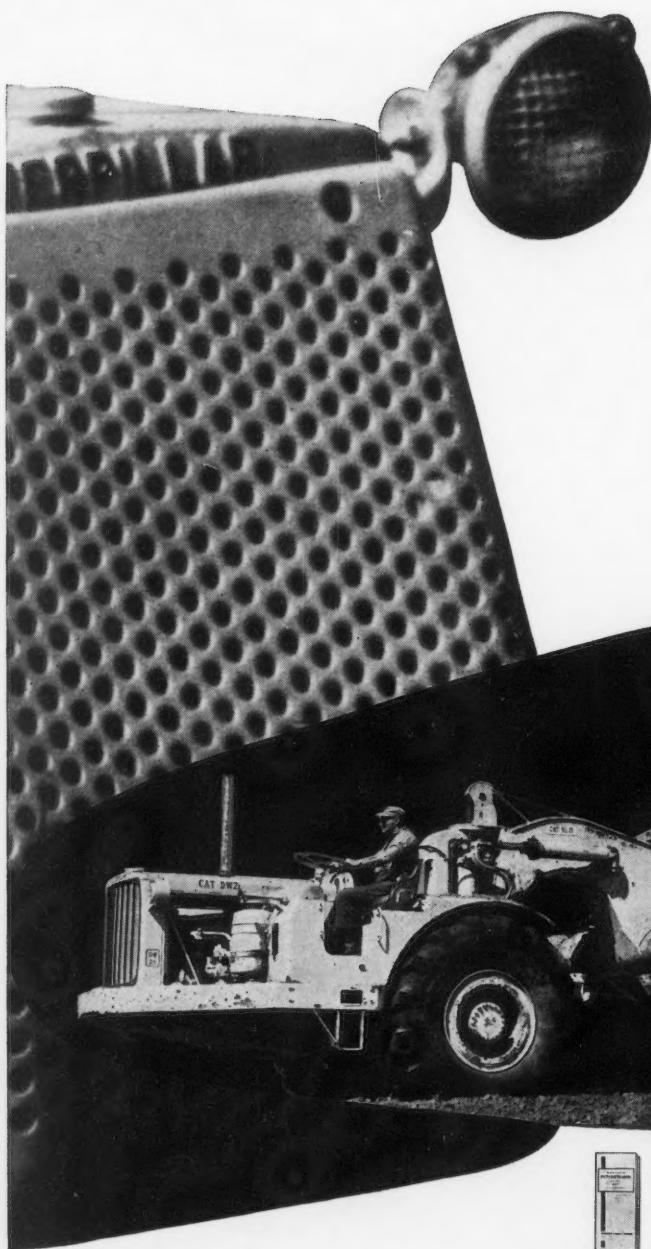
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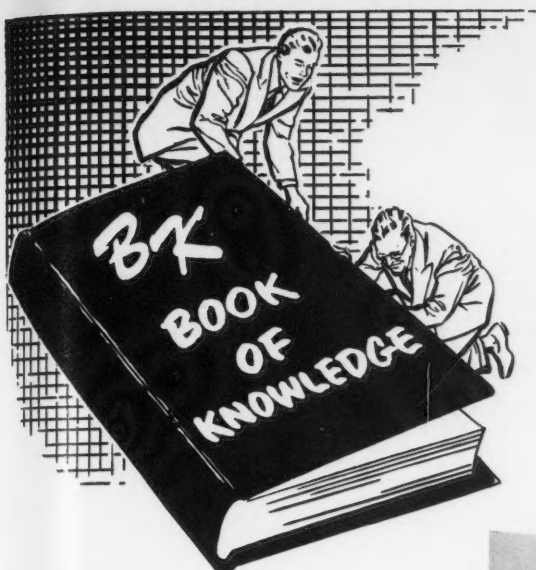


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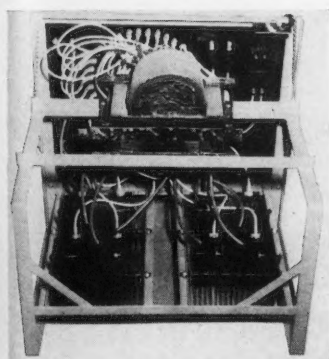
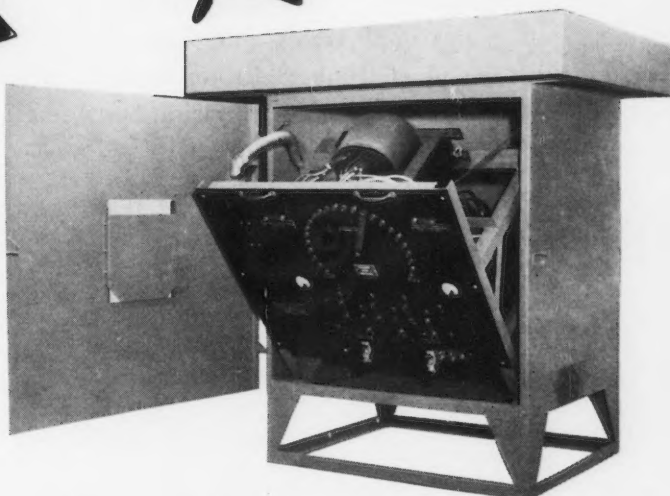


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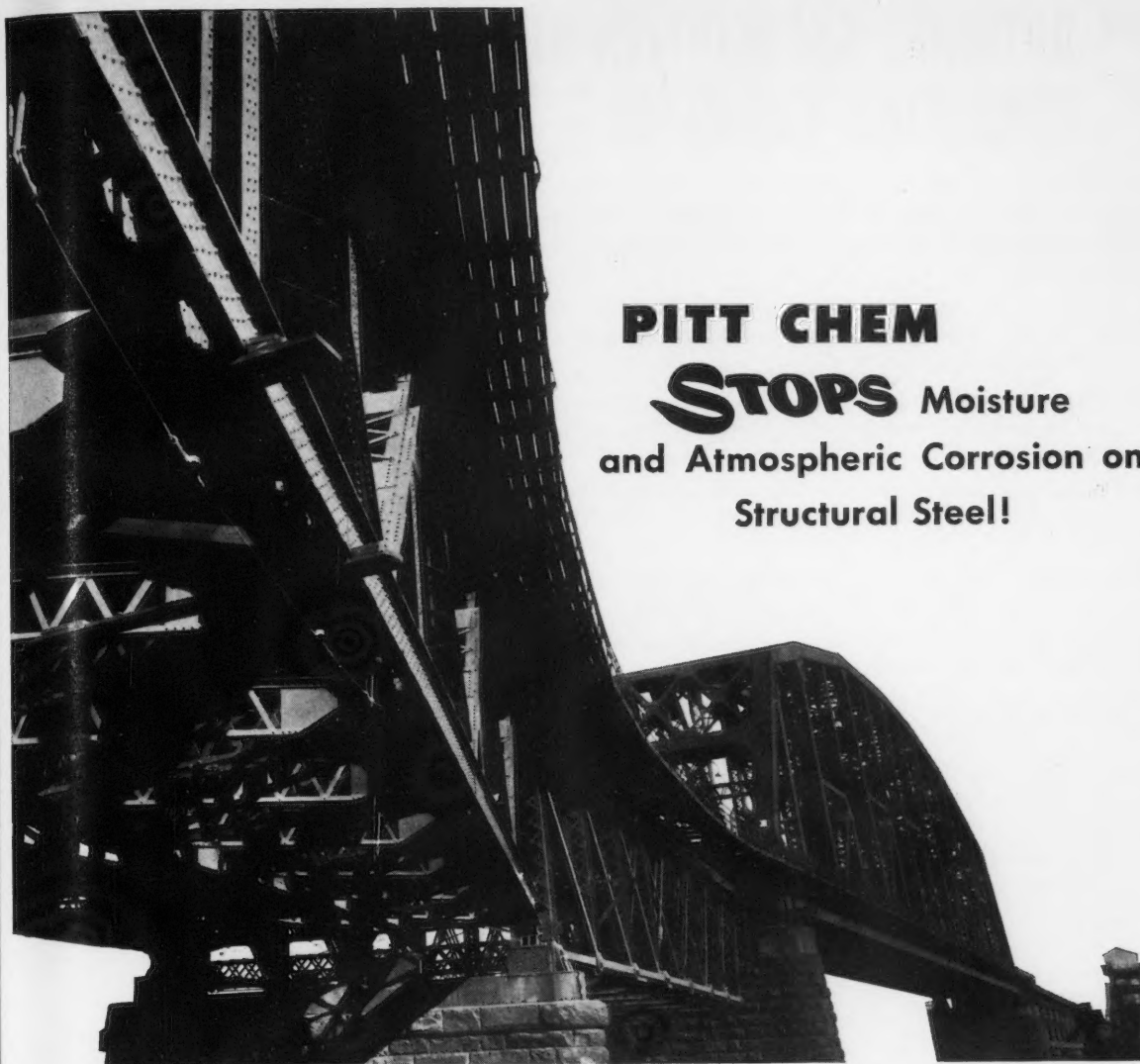
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## Corrosion Instruments and Measurements Handbook Is Committee's Objective

By H. N. HAYWARD\*, Chairman

AFTER being inactive for a considerable period, TP-14 has been reorganized. The initial meeting of the reactivated committee was held during the National Association & Engineers Conference in Chicago in March, when the scope of the proposed activities of the committee was discussed. There were approximately 45 guests at this meeting, which is an indication of the interest in the subject of corrosion instruments and measurements.

The committee's first project will be to work toward preparation of a fairly complete corrosion instruments and measurements handbook, possibly in cooperation with the American Gas Association, because of the interest expressed in such an undertaking at the Chicago meeting. It was recommended that the handbook contain adequate information covering the proper application and utilization of instruments, which was not fully accomplished in the AGA handbook now available, which consists primarily of manufacturers descriptive literature except for a brief section in the front of the book.

It also has been recommended that a sub-committee be formed to do something about standardizing corrosion measurements and evaluating statistical data obtained from them. An indication of interest in this subject by NACE members would be appreciated.

\* University of Illinois, Urbana.

Another activity suggested for the committee is that it work toward standardization of the ranges and characteristics of instruments used for corrosion measurements. There is now a considerable variation in the instruments available, some of which are not too well suited for corrosion measurements.

The need for recording instruments for use in making stray current studies has been stressed and it has been pointed out that instruments currently available lack some desired features. It has been recommended that the committee undertake to work with recorder manufacturers in an attempt to have needed improvements incorporated.

So far, the only sub-committee is TP-14A on Coating Holiday Inspection and Standards. The chairman reports that the plans for this sub-committee include:

1. Pipe line inspection before burial.
2. Tank bottom inspection.
3. Pipe line inspection after burial.

Work on the first subject has been started and the remaining two will be given attention later. The sub-committee is made up of representatives of manufacturers, users and coating companies in order to have all areas interested in holiday inspection represented. It planned that the working sub-committee will be kept small and that its findings will be reported to a larger group before being released.

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# Fundamental Concepts of Electrode Potentials\*

By ANDRE J. deBETHUNE

AT THE OUTSET of any discussion of electrode potentials, it is well to recall these words of Willard Gibbs, the founder of thermodynamic electro-chemistry:<sup>1</sup>

The consideration of the electrical potential in the electrolyte, and especially the consideration of the difference of potential in electrolyte and electrode, involves the consideration of quantities of which we have no apparent means of physical measurement, while the difference of potential in "pieces of metal of the same kind attached to the electrodes" is exactly one of the things which we can and do measure.

Any measurement of electrode potentials presupposes the presence of a second or reference electrode, the potential difference measured is that between the leads connecting the electrodes to the voltmeter or potentiometer. The *absolute potential difference* between *metal* and *electrolyte* cannot be measured and is therefore a scientifically meaningless concept. By adopting a constant reference electrode, changes in the metal-electrolyte potential difference can be measured and become scientifically meaningful.

Once the *reference electrode* is clearly defined, or, at least, understood, it becomes licit to talk about the *potential of a single electrode*.

Two important reference electrodes are: 1) the standard hydrogen electrode (SHE) and 2) the saturated calomel electrode (SCE). The SHE consists of a platinized platinum wire saturated with hydrogen gas at a pressure of 1 atmosphere in the presence of an electrolyte containing hydrogen ions at unit activity (e.g. approximately 1 molal HCl). The SCE is an electrode of mercury covered with a paste of calomel ( $\text{Hg}_2\text{Cl}_2$ ) and an electrolyte of saturated KCl. A cell consisting of one SHE and one SCE has an open-circuit emf of 0.245 volts at 25 degrees C (77 degrees F) with the SCE connected to the + terminal of the potentiometer. (Figure 1.)

For the most exact purposes, it is often necessary to measure the emf of a cell or battery without drawing any current from it (open-circuit emf). This can be done approximately with a high resistance DC voltmeter and exactly with a vacuum-tube voltmeter, or with a potentiometer (Poggendorf compensation method).<sup>2</sup>

## Types of Electrode Potentials

When a piece of metal is dipped into a conducting liquid, a reference electrode introduced and the potential difference measured, one finds in general that the potential of the metal does not reach any steady value but fluctuates erratically with time. The events at the electrode-liquid interface which deter-



ANDRE J. deBETHUNE—Associate Professor of Chemistry, Boston College, Chestnut Hill, Mass., since 1949, Prof. deBethune is a native of Belgium, but has been in the United States since 1928. His research includes investigations of hydrogen overvoltage, gaseous diffusion and permeabilities and electrode processes. With degrees from St. Peter's College (1939) and Columbia University (1945) he has been research associate with Manhattan Project Laboratories, Columbia University Division of War Research and Carbide and Carbon Chemicals Corp., 1942-45. He was National Research Fellow with Prof. G. Scatchard at MIT, 1945-47, and has been at Boston College since. He belongs to numerous professional organizations and is consultant to Carbide and Carbon Chemicals Corp., Oak Ridge, Tenn.

## Abstract

The potential differences observed at metal liquid interfaces arise as a result of two distinct phenomena: 1) at reversible electrodes, phenomena associated with Faraday's Law; 2) at polarized electrodes, phenomena associated with the charging of the double layer. At reversible (or nearly reversible) electrodes, electricity can flow through the interface by the mechanism of an electron exchange reaction between the metal and the chemicals present at the electrode surface. When electrons are donated by the metal (reduction), the electrode is a cathode. When electrons are removed by the metal (oxidation), the electrode is an anode. When electron exchange is at equilibrium, the electrode potential is governed by the Nernst equation. A kinetic derivation of this equation is given. Its two terms, the standard potential term, and the Mass Action term are discussed. The standard hydrogen electrode (SHE) provides a convenient reference point from which to measure electrode potentials. The conventions regarding the signs and nomenclature of electrode potentials are reviewed.

With a net current flowing, the electron exchange is not at equilibrium and the potential of the electrode is displaced from the reversible Nernst value (polarization potential). Polarization as an anode shifts the potential in a more noble direction; as a cathode, in a less noble direction. The application of cathodic polarization to the cathodic protection of a metal is discussed. The properties of the electrical double layer at an ideal polarized electrode are surveyed both from the point of view of the potential of zero charge (the isoelectric point of the electrode) and from the point of view of the differential capacity of the double layer.

mine the potential may be enormously complicated and may differ on different portions of the same metal surface (local cells, oxide films, passivation, metal strain, competing reactions, etc.). As the nature of the surface varies with time, so does the potential. Yet it takes only very minute amounts of material to alter radically the nature of a surface, e.g. a monolayer of water covering 1 square foot weighs only 1 micro-ounce. This example shows that rather severe conditions of chemical purity may be required before electrode potentials become reproducible.

There are two limiting cases where reproducible

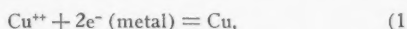
\* A paper delivered at the Ninth Annual Conference, National Association of Corrosion Engineers, Chicago, Ill., March 16-20, 1953.



electrode potentials can be measured, viz., at reversible electrodes, and at (ideally) polarized electrodes. A reversible electrode is one at which only one single electro-chemical reaction is occurring (with 100 percent current efficiency) and is at equilibrium (or nearly so). The potential is determined by this reaction according to the Nernst equation. An (ideally) polarized electrode<sup>3</sup> is one at which the transfer of electricity between metal and electrolyte is inhibited: charges move up to the interface but do not cross it (electrical double layer). The potential is determined by the charge and capacitance of the double layer.

### Potentials at Reversible Electrodes

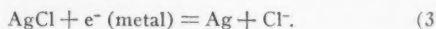
At reversible (or nearly reversible) electrodes, electricity crosses the interface by the mechanism of an electron exchange reaction which occurs with 100 percent current efficiency according to Faraday's Law. When electrons are donated by the metal to the surrounding materials, the chemical reaction is a reduction and the electrode is called a *cathode*. Examples of cathodic reductions include the plating out of a metallic cation,



the reduction of a neutral molecule,



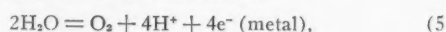
the reduction of the electrode material itself (as in a silver chloride coated silver electrode),



When electrons are removed by the metal from the surrounding materials, the chemical reaction is an oxidation and the electrode is called an *anode*. Examples of anodic oxidations include the discharge of an anion,



the oxidation of a neutral molecule,



the anodic corrosion of the electrode,



When two electrodes are dipped in a conducting liquid and a potential difference is found, the electrode connected to the + terminal of the potentiometer has the more noble potential. In a galvanic cell, e.g. a discharging battery, the more noble electrode (the + terminal) acts as a cathode and the less noble electrode (the - terminal) acts as an anode. When the direction of the current is reversed, e.g. by recharging the battery, the cell becomes an electrolytic cell in which the more noble electrode (the + terminal) acts as an anode and the less noble electrode (the - terminal) acts as a cathode. In a galvanic cell, positive current flows from the - to the + terminal inside the battery. In an electrolytic cell, positive current flows from the + to the - terminal inside the battery. In either case, positive current always flows from the anode to the cathode inside the battery. Therefore, an electric current will always carry cations to the cathode and anions to the anode

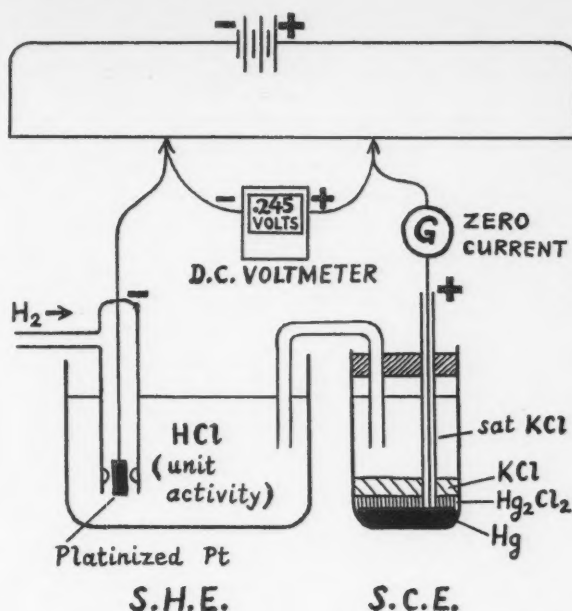


Figure 1—A cell made up of a standard hydrogen electrode (SHE) and a saturated calomel electrode (SCE). "Open circuit" electromotive force measured with a potentiometer by the Poggendorf compensation method.

regardless of the mode of operation of the battery (galvanic or electrolytic) and regardless of whether the anode (or cathode) is located at the + or at the - terminal. Any given electrode can function either as an anode or as a cathode depending on the electrode with which it is paired and on the manner of operation of the cell.

At the surface of any reversible electrode, the electrode reaction occurs simultaneously in both the anodic and the cathodic direction. When the rates of the two opposing reactions become equal, the electrode reaches a state of dynamic equilibrium and its potential is given by the Nernst equation.<sup>4</sup> This equation can be derived rigorously from thermodynamics. However, a kinetic derivation illustrates better some of the physical aspects and is therefore given below.

Suppose an electrode of the metal M dipping in a solution containing the ions  $M^+$  plus negative ions to neutralize the charge. At the surface of the electrode, there occurs the reaction:



Let  $r_1$  be the rate of the forward or cathodic process, and  $r_2$  the rate of the reverse or anodic process. By the Law of Mass Action, the rate  $r_1$  should be proportional to the activity\* of the  $M^+$  ions in solution, i.e.,  $r_1 = k_1(M^+)$ ; and the rate  $r_2$  should be proportional to the activity of the M atoms in the surface of the metal, i.e.,  $r_2 = k_2(M)$ , where  $k_1$  and  $k_2$  are rate constants.

\*The activity of any substance is rigorously defined in thermodynamics and it is a quantity which increases when the chemical potential (or partial molal free energy) of the substance increases. For present purposes, consider the activity of the ions to be given approximately by their molal concentration (number of gram-moles of ions per kilogram of solvent); while the activity of the metal atoms may be taken as equal to what Nernst originally called their "solution pressure."

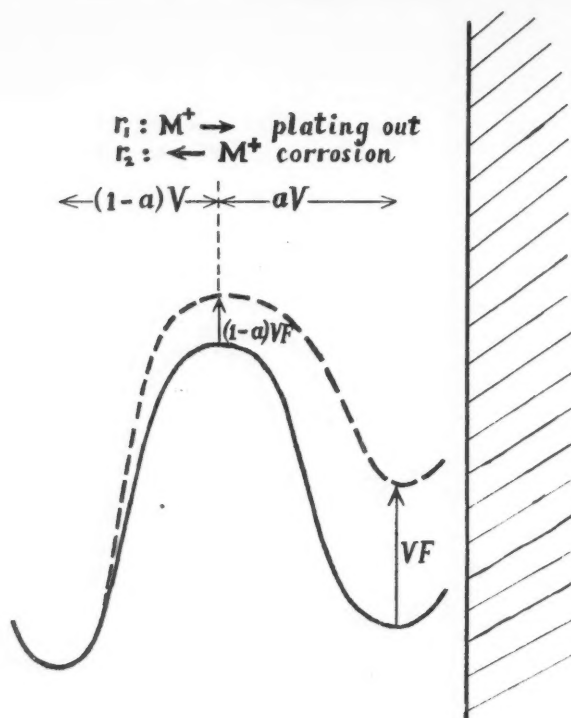


Figure 2—The potential energy barrier at an electrode surface.

These expressions are too simple, however, in that they neglect the effect of the electrode potential. The metal  $M$  can be visualized as a crystalline lattice of  $M^+$  ions surrounded by an electron gas made up of the valence or conduction electrons of the metal atoms. Reaction 7 may therefore be more correctly represented as



i.e.: as the transfer of an ion  $M^+$  from the solution to a lattice point in the metal surface. Suppose that the metal is polarized to a positive\* or noble potential  $V$  (referred to the SHE). This positive potential repels the ions  $M^+$  away from the metal towards the solution. It thus slows down the cathodic plating-out rate  $r_1$  and promotes the anodic corrosion rate  $r_2$ .

Suppose further that the ion  $M^+$  must cross some sort of a potential energy barrier in going through the interface. In Figure 2, the solid curve represents this potential energy barrier when  $V = 0$  (i.e., when the electrode is at the potential of the SHE). The polarization of the electrode to a positive potential  $V$  raises the potential energy of the ions  $M^+$  in the electrode surface by an amount  $VF$  per gram-ion ( $F$  is the Faraday) up to the dotted curve. If the fraction  $a$  of the potential  $V$  operates between the metal surface and the top of the barrier and the fraction  $1-a$  between the top of the barrier and the bulk of the solution, it is apparent from an inspection of Figure 2 that the height of the barrier

is raised by the amount  $(1-a)VF$  for process 1. For process 2, the summit of the barrier is raised by  $(1-a)VF$  but the base is raised by  $VF$  so that the net height of the barrier is lowered by  $aVF$ .

Chemical kinetics teaches that the rate of a chemical reaction is proportional to the exponential of  $-E/RT$ , when the reaction has to overcome a potential energy barrier of height  $E$ , ( $R$  is the gas constant,  $T$  the absolute temperature or  $^{\circ}\text{C} + 273$ ). Therefore the effect of the potential  $V$  on the rate of the plating-out reaction can be represented by the equation

$$r_1 = k_1 (M^+) \exp [-(1-a)VF/RT], \quad (9)$$

where the effect of the positive potential  $V$  is to cause an exponential decrease in the plating-out rate. On the other hand, for the corrosion reaction, the positive potential lowers the net height of the energy barrier so that we obtain the equation:

$$r_2 = k_2 (M) \exp (+aVF/RT) \quad (10)$$

where the effect of the positive potential  $V$  is to cause an exponential increase in the corrosion rate.

When the electrode is polarized to a negative potential,  $V$  becomes a negative quantity. Inspection of equations (9) and (10) shows that in this case the plating-out reaction is speeded up and the corrosion reaction slowed down.

When the two opposing rates are equal, the electrode is at equilibrium. By equating the expressions in (9) and (10), solving for  $V$  and going from exponentials to natural logarithms, we obtain the Nernst equation in the form

$$V = (RT/F) \ln k_1/k_2 + (RT/F) \ln (M^+)/M. \quad (11)$$

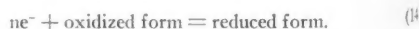
Suppose now that both activities can be set equal to unity. This presupposes that the electrode is chemically pure and in a strain-free condition and that the solution contains ions at an activity (approximately, at a concentration) of 1 gram-mole per kilogram of solvent (1 molal). This is the "standard state" of the  $M$  electrode. By substituting  $M = (M^+) = 1$  in equation (11), it is seen that the potential of the electrode in the standard state, designated by  $V^{\circ}$ , is given by

$$V^{\circ} = (RT/F) \ln k_1/k_2. \quad (12)$$

At room temperature  $RT/F = 0.026$  volts. After conversion to common logarithms, the Nernst equation is obtained in its usual form

$$V = V^{\circ} + (0.060 \text{ volts}) \log (M^+)/M. \quad (13)$$

In general, any reversible electrode reaction can be written as



By an argument analogous to that developed above, it can be shown that the Nernst equation then becomes

$$V = V^{\circ} + \frac{0.060 \text{ volts}}{n} \log \frac{(\text{ox})}{(\text{red})} \quad (15)$$

where (ox) and (red) denote the activity (or the product of activities) of the oxidized and reduced materials respectively, and  $n$  is the number of electrons involved in the oxidation-reduction step.

\* This is the so-called "European" convention, by which an electrode more noble than the SHE is assigned a positive potential value. The opposite "American" convention is discussed further in the text.

TABLE I  
The Electromotive Series at 25°C (77°F)

ELECTRODE	Standard Potential, $V^\circ$ (Referred to the SHE) Volts	
K <sup>+</sup>  K	-2.92	
Na <sup>+</sup>  Na	-2.71	
Mg <sup>2+</sup>  Mg	-2.34	
Al <sup>3+</sup>  Al	-1.67	
Zn <sup>2+</sup>  Zn	-0.76	
Fe <sup>2+</sup>  Fe	-0.44	
Pb <sup>2+</sup>  Pb	-0.13	
Fe <sup>3+</sup>  Fe	-0.04	
H <sup>+</sup> , H <sub>2</sub>  M* (SHE)	0.00	
KCl (sat), Hg <sub>2</sub> Cl <sub>2</sub>  Hg (SCE)	(+0.245)**	
Cu <sup>2+</sup>  Cu	+0.34	
Γ <sup>-</sup> , I <sub>2</sub>  M	+0.53	
Ag <sup>+</sup>  Ag	+0.80	
Br <sup>-</sup> , Br <sub>2</sub>  M	+1.07	
H <sup>+</sup> , H <sub>2</sub> O, O <sub>2</sub>  M	+1.23	
Cl <sup>-</sup> , Cl <sub>2</sub>  M	+1.36	
Au <sup>3+</sup>  Au	+1.50	
F <sup>-</sup> , F <sub>2</sub>  M	+2.87	

↑  
Less Noble Potentials  
More Noble Potentials  
↓

\* M in this table denotes an inert metal electrode which acts merely as a donor or acceptor of electrons. Platinum is often used for that purpose.  
\*\* This is not a standard potential, since the SCE is not a standard state electrode. The potential of the standard state calomel electrode is +0.268 volts.

### Interpretation of Standard Potentials

The most important characteristic of an electrode is the value of its *standard potential*  $V^\circ$ . A tabulation of the electrodes according to their standard potentials is called the *electromotive series*. Table I gives a brief selection of electrodes taken from this series.<sup>5</sup> Close to the top will be found the active electropositive metals, such as potassium, sodium and magnesium which have a strong chemical tendency toward corrosion. At the bottom will be found the noble metals such as silver and gold and the active electronegative non-metals such as fluorine and chlorine. *The lower an electrode appears in the series, the more noble its potential.*

The electromotive series gives a clue to the relative oxidizing and reducing power of substances. The metals (and all other reducing agents such as H<sub>2</sub> or I<sup>-</sup>) are listed in order of decreasing reducing power. The non-metals (and all other oxidizing agents such as Au<sup>3+</sup> or H<sup>+</sup>) are listed in order of increasing oxidizing power. There is a simple rule for determining whether or not any given oxidation-reduction reaction is possible; *a reducing agent can react with any oxidizing agent below it in the series; an oxidizing agent can react with any reducing agent above it in the series.* For example, zinc metal can reduce hydrogen ions but not magnesium ions, hydrogen ions can corrode iron but not copper.

If the oxidation and reduction steps can be made to occur at two separate electrodes with the electrons transferred through an external wire, a cell or battery is created which can act as a source of electric power. In this case, the electrode lower in the series, with the more noble potential, is the + terminal of the cell. It acts as a cathode on discharge\* and as an anode on recharge. For example, in the zinc-copper cell (the Daniell cell), copper is the + terminal. The emf of the cell can be taken as the algebraic difference of the two electrode potentials, i.e.: +0.34 volts for the copper minus -0.76 volts for the zinc gives an emf of 1.10 volts. On dis-

charge, the zinc anode corrodes and copper ions plate out. On recharge, the zinc ions are made to plate out and the copper is redissolved.

The electromotive series also gives a clue to the order in which anode and cathode reactions occur in electrolysis. At the cathode, the ion easiest to reduce plates out first, e.g.: Cu<sup>2+</sup> before Pb<sup>2+</sup> before Fe<sup>2+</sup> before Zn<sup>2+</sup>. This order can be disturbed in actual practice by the appearance of irreversible effects, e.g.: hydrogen over-voltage which may shift the discharge potential of H<sup>+</sup> several tenths of a volt in the less noble direction.

The *standard potential* of an electrode is governed by an interesting thermodynamic relation. Equation (12) contains the expression  $k_1/k_2$  which is nothing else than the equilibrium constant  $K$  for reaction (7 at  $V = 0$ , (i.e., at the potential of the SHE). Therefore, it is possible to compute  $K$  from  $V^\circ$  by means of equation (12, e.g.: for the sodium electrode,

$$-2.71 \text{ volts} = (0.060 \text{ volts}) \log K.$$

Therefore,  $\log K = -2.71/0.06 = -45$ , and  $K = (\text{Na})/(\text{Na}^+) = 10^{-45}$ , i.e. the concentration of sodium metal in equilibrium with 1 molal Na<sup>+</sup> ion (at the potential of the SHE) amounts to about one atom of metallic sodium in a volume the size of the earth's!

Recall the well known thermodynamic equation

$$\Delta G^\circ = -RT \ln K, \quad (16)$$

where  $\Delta G^\circ$  is the standard increment in free energy for the chemical reaction whose equilibrium constant is  $K$ . Equation (12) can then be rewritten as

$$V^\circ = -\Delta G^\circ/F. \quad (17)$$

For reaction (7, the standard free energy change is equal to

$$\Delta G^\circ = \bar{G}^\circ(\text{M}) - \bar{G}^\circ(\text{M}^*), \quad (18)$$

i.e., the difference in standard chemical potential (standard partial molal free energy)  $\bar{G}^\circ$  between the metal and its ion.\* Therefore,

$$V^\circ = [\bar{G}^\circ(\text{M}^*) - \bar{G}^\circ(\text{M})]/F, \quad (19)$$

i.e., the standard electrode potential is equal to the standard increase in chemical potential of the metal when it ionizes (corrodes) per Faraday of ions produced.

### The Electrochemical Law of Mass Action

When the activity of the metal or of its ion differs from unity, the reversible electrode potential  $V$  differs from the standard value  $V^\circ$ . This is the case, for instance, when the metal is not pure but is alloyed or amalgamated, or when the activity (concentration) of the ion has a value different from 1 molal. In this case, the electrode potential  $V$  must be determined from the full Nernst equation: equation (13 for a univalent metal, equation (15 for a  $n$ -valent metal. Because the

\* To be strictly accurate,  $\Delta G^\circ$  is the standard free energy change for the reaction  $\text{M}^+ + \frac{1}{2}\text{H}_2 = \text{H}^+ + \text{M}$ . The adoption of the SHE as a zero of potential is equivalent to the arbitrary convention that  $\Delta G^\circ$  for the reaction  $\frac{1}{2}\text{H}_2 = \text{H}^+ + \text{e}^-$  is equal to zero. This convention must be kept in mind when interpreting equations (18 and (19).

\* This fact accounts for the Corrosion Handbook's designation of more noble potentials as "cathodic" and less noble potentials as "anodic."



Nernst equation involves the activity of both the metal (reduced form) and of the ion (oxidized form), it may well be called the Electrochemical Law of Mass Action.

Suppose that the metal M is present in an amalgam. Its activity is therefore less than that of the pure metal. The "solution pressure" of the metal is decreased, its tendency toward corrosion lessened, the metal acts more like a noble metal. Its reversible potential should therefore be shifted to a more noble value. By inspection of equations (13 and (15), it is seen that the activity ratio  $(M^+)/M = (ox)/(red)$  is increased, and that  $V$  is shifted to a higher (positive) value, i.e. to a more noble value.

Suppose instead that the activity of the ion  $(M^+)$  is decreased. The plating-out tendency of the ion is thereby lessened and the corrosion tendency of the metal enhanced. The metal becomes a better reducing agent, a more active metal. Its reversible potential should be shifted to a less noble value. By inspection of equations (13 and (15), it is seen that the activity ratio  $(M^+)/M = (ox)/(red)$  is decreased and that  $V$  is shifted to a lower (positive) value, i.e. to a less noble value.

There are many practical applications of the Nernst equation. Only two of them will be sketched: the determination of pH,<sup>6</sup> and the measurement of the solubility of slightly soluble salts. For the determination of pH, a cell of the type depicted in Figure 1 can be used. Suppose that the HCl solution of unit activity is replaced by a solution of unknown pH. The potential of the hydrogen electrode HE is shifted from its standard value  $V^\circ$  ( $= -0.245$  volts when the SCE is used as the reference electrode) to the value

$$V(HE) = -0.245 + (0.060/1) \log (H^+)/(H_2)^{1/2} \quad (20)$$

For hydrogen gas at 1 atmosphere pressure,  $(H_2) = 1$ . Recall the definition  $pH = \log 1/(H^+) = -\log (H^+)$ . The potential of the hydrogen electrode becomes

$$V(HE) = -0.245 - 0.060 \text{ pH}, \quad (21)$$

i.e., the hydrogen potential is shifted 60 millivolts in a less noble direction for every unit increase in the pH. The emf of the whole cell then becomes equal to 0.245 volts + 0.060 pH volts and can be used to compute the unknown pH.

The solubility of slightly soluble salts can be determined from the Nernst equation as illustrated in the following example. The standard potential of silver is +0.80 volts (Table I). A pure silver electrode dipped in a solution saturated with silver chloride and containing 1 molal chloride ion has a potential of +0.22 volts. Apply the Nernst equation to these facts:

$$+0.22 = +0.80 + (0.060/1) \log (Ag^+)/(Ag).$$

For pure silver,  $(Ag) = 1$ . Therefore,  $\log (Ag^+) = (0.22 - 0.80)/(0.06) = -9.7$  and  $(Ag^+) = 2 \times 10^{-10}$ . Since  $(Cl^-) = 1$ , the solubility product  $(Ag^+)(Cl^-) = 2 \times 10^{-10}$ . For a salt of this valence type, the solubility is equal to the square root of the solubility product, viz.,  $1.4 \times 10^{-5}$  gram-moles per Liter.

## Note Regarding the Sign of the Electrode Potential

The sign convention followed in this paper was first adopted by the German Bunsen Gesellschaft<sup>7</sup> and is used by the Faraday Society and by the Electrochemical Society. This convention is universally used in Europe,<sup>8</sup> hence the name "European," but it is also widely used in this country by practical electrochemists,<sup>9,10</sup> analytical chemists,<sup>11</sup> physicists,<sup>12</sup> and engineers.<sup>13,13a</sup>

The alternative convention, viz., that of assigning a positive value to the potential of an electrode less noble than the SHE, was promulgated by G. N. Lewis,<sup>14,15</sup> and is extensively followed by American physical chemists,<sup>2,5,6</sup> hence the name "American." In particular, Latimer's work<sup>5</sup> which contains the best collection of electrode potentials, uses it.

Because the coexistence of these two conventions has created untold confusion in the minds of many, their principal features will be briefly reviewed here. The electrode potential according to the European convention can be taken as equal to the potential difference

$$V(\text{metal}) - V(\text{electrolyte}),$$

to within an arbitrary additive constant. The electrode potential according to the American convention is then equal to the potential difference

$$V(\text{electrolyte}) - V(\text{metal}),$$

to within an arbitrary additive constant.

The great advantage of the European convention rests in the fact that the sign of the electrode potential corresponds to the polarity of the electrode as determined with any DC potential measuring device. Of any two electrodes paired together to form a cell, the one with the higher (positive) potential is the + terminal.

There is one paradox in the European convention, namely: electropositive elements (K, Na) have negative electrode potentials, and electronegative elements (F, Cl) have positive electrode potentials. This paradox is easy to resolve, however. Consider sodium, a strongly electropositive element. In the  $Na^+ | Na$  couple, there is a strong tendency for the sodium atoms to be corroded, forming positively charged sodium ions and leaving their electrons behind to give a negative charge (and therefore a *negative potential*) to the metal. On the other hand, electronegative elements have a strong tendency to remove electrons from an electrode to form negatively charged ions and thus to leave the electrode with a positive charge (and with a *positive potential*).

The American convention assigns positive potentials to the electropositive elements and *vice-versa*. But it embraces the paradox that electrode potential and electrode polarity as determined in the laboratory should be opposite in sign. The following instruction is taken from a well known laboratory manual of physical chemistry which follows the American convention:<sup>16</sup>

... if it is found in the laboratory that the electrode M is the negative electrode, the measured electromotive force is given a positive sign. If the electrode M is found to be the positive electrode, then the measured electromotive force is written as a negative quantity.

It is sincerely to be hoped that this unnecessary and costly confusion may be ended by some definitive international agreement. In the meantime, the author would like to recommend the practice followed in the present paper, viz.: to take advantage of the one loophole allowed by Lewis and Randall<sup>17</sup> in their great work. This loophole consists in always writing electrodes in the order

solution | metal

and electrode reactions as reductions in which electrons are consumed, as in equations (7 and (14. If this is done, the thermodynamic conventions of Lewis and Randall not only permit but require the use of the European sign convention.\*

As regards the designation of potentials by names, it is apparent by now that the terms *positive* and *negative* have been hopelessly confused by the disagreement between the two sign conventions. The terms suggested by the Corrosion Handbook, viz., *anodic* and *cathodic potentials*, are not unambiguous either as witness the following quotation from that work<sup>18</sup>

... the electrode will polarize anodically and its potential will be altered in the cathodic direction.

The only terms which this author has found to be devoid of confusion are the terms *noble* and *active potentials*, referring to the potentials of *metals more noble* (or *more active*) than *hydrogen*, respectively. In this way potentials can be referred to as more noble or less noble, or more active or less active. In the present paper, the terms *more noble* and *less noble* are used exclusively, together with the European sign convention.

A summary of the different conventions regarding signs and designations of electrode potentials is given in Table II.

### Polarization of An Electrode

In the derivation of the Nernst equation, the important assumption is made that the electrode is *at equilibrium*, i.e. the rates of the opposing cathodic and anodic processes, equations (9 and (10, can be set

\* In the Lewis and Randall convention, a positive potential value represents a spontaneous tendency for positive electricity to cross the interface from left to right. Therefore the sign of their electrode potential changes when the order of writing the electrode is changed from metal/solution to solution/metal, notwithstanding the fact that the polarity of the electrode in any given cell does not change when the order of writing the electrode changes.

TABLE II  
Signs and Designations of Electrode Potentials

Polarity of the electrode with respect to the S.H.E. (or with respect to the other electrode in the cell).....	+	-
Potential designation on the noble-active scale.	noble more noble* less active	active less noble* more active
European sign convention* (also Lewis and Randall for $M^+ M$ and $e^- + M^+ = M$ ).....	+*	-*
American sign convention (Lewis and Randall for $M M^+$ and $M = M^+ + e^-$ ).....	-	+
Direction of Current Flow in a Galvanic Cell (also Corrosion Handbook designation for the potential).....	cathodic	anodic
Direction of Current Flow in an Electrolytic Cell (also polarization potential).....	anodic	cathodic

\* Conventions recommended in the present paper.

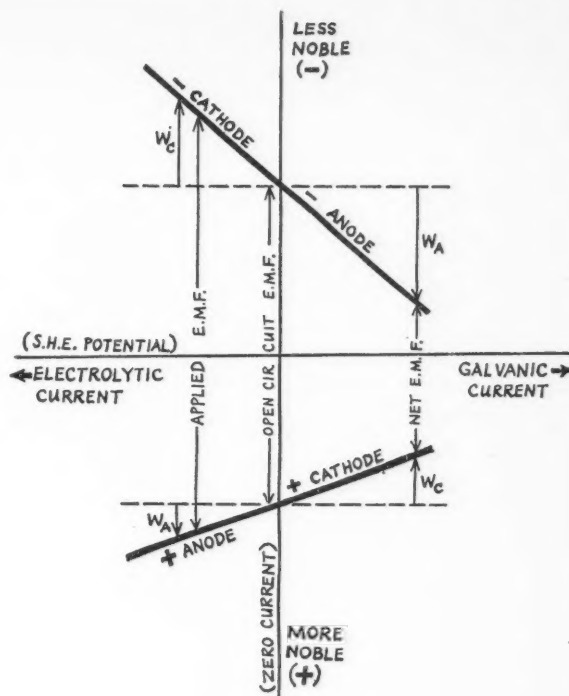


Figure 3—Polarization of a cell.

equal. When a net current flows through the electrode-solution interface, the potential is often different from the equilibrium (reversible) value given by the Nernst equation\* (13 or (15. The change in potential is known as a polarization potential or an overvoltage. It may be looked upon as an additional emf needed to push the current through a resistance (of whatever chemical or mechanical nature) localized at or near the electrode surface.

The direction of this potential shift can be simply related to the direction of current flow. In the derivation of the Nernst equation, it is seen that a positive (more noble) potential opposes the cathodic (plating-out) reaction and promotes the anodic (corrosion) reaction. Therefore it can be concluded that a potential shift in the more noble direction will yield a net anodic current. Conversely, a potential shift in the less noble direction will yield a net cathodic current. Expressed mathematically,

$$V_a = V_e + W_a, \quad (22)$$

$$V_c = V_e - W_c, \quad (23)$$

where  $V_a$  (or  $V_c$ ) is the potential of a working anode (or cathode),  $V_e$  is the equilibrium Nernst potential, and  $W_a$  and  $W_c$  are the anodic and cathodic polarizations, respectively. The symbol  $W$  is used to designate the absolute magnitude of the polarization potential regardless of the direction of the shift.

The effect of polarization on the electrode potentials of a cell is sketched in Figure 3. The vertical axis is a potential axis with negative (less noble) potentials at the top (as in the Electromotive Series). The horizontal axis is a current axis with galvanic

(discharging) currents increasing to the right, and electrolytic (charging) currents increasing to the left. The heavy lines represent the dependence of the two electrode potentials on the current, e.g., the + terminal suffers a cathodic polarization  $W_c$  on discharge and an anodic polarization  $W_a$  on charge (the converse is true of the — terminal). At zero current, the vertical distance between the two curves is equal to the open circuit emf of the cell. On discharge, polarization pulls the electrode potentials together and the net emf of a discharging battery is less than the open circuit emf. On charge, polarization pushes the electrode potentials apart and the applied charging emf must be greater than the open circuit emf.

Note that the polarization curve for the + terminal has been sketched more nearly horizontal than that for the — terminal. This means that the + terminal, in this case at least, is more nearly reversible (less polarizable) than the — terminal.

Polarization curves are not necessarily straight lines and they can assume very complicated shapes (e.g., the staircase shaped curve of the polarograph). There are three principal mechanisms by which polarization arises: concentration, resistance and activation polarizations.<sup>19</sup>

If the passage of a current alters the concentration (activity) of the ion ( $M^+$ ) = (ox) in the immediate vicinity of an otherwise reversible electrode, its Nernst potential (13 or 15) is thereby modified from the zero-current (reversible) value. This is known as concentration polarization. In general, this type of polarization does not exceed values of the order of one or two tenths of a volt, it is often characterized by the appearance of limiting currents (as in polarography) and it can always be lessened by rotation or stirring of the electrode.

If the electrode-solution interface has an appreciable resistance, due to a very dilute electrolyte near the electrode or to an oxide or other film, the electrode potential includes an ohmic term of the form  $iR$ . This is known as resistance polarization. This type of polarization always gives a linear relation between current and potential.

If the electrode reactions are inherently slow, i.e., the rate constants  $k_1$  and  $k_2$  of equations (9 and (10 are very small, a large polarization voltage (of the order of 1 volt) must be applied to drive an appreciable current through the interface. In this case, the height of the potential energy barrier (activation barrier, Figure 2) is high (e.g., for hydrogen overvoltage on mercury, it is 0.95 Faraday-volts), so that one can speak of an activation polarization. From equations (9 and (10, it is seen that this type of polarization gives rise to a current exponentially dependent on the potential, i.e., the logarithm of the current is a linear function of the potential. This type of relation was discovered experimentally by Tafel,<sup>20</sup> and verified by many workers.<sup>21, 22</sup>

### Cathodic Protection

In the discussion of equations (9 and (10 it was pointed out that a negative (less noble) potential promotes the plating-out reaction and slows down

the corrosion reaction. Thus it induces a net cathodic current. A metal can, therefore, be protected against corrosion by cathodic polarization, i.e., by making it the seat of a net cathodic current.

Figure 3 suggests two ways in which this can be accomplished: 1) by pairing the metal with a more active (less noble) metal with which it forms a galvanic cell. The more active metal (e.g. magnesium) becomes a sacrificial anode and is corroded in preference to the protected metal; 2) by pairing off the metal with any anode and polarizing it as a cathode by means of an externally applied direct current emf. In this case, the sacrificial corrosion of the anode may still be expected.<sup>23</sup>

There is an interesting paradox to note here. If the potential of a metal is shifted in a negative (less noble) direction by operation of the Mass Action effects contained in the Nernst equation, i.e. by a shift in the activities ( $M$ ) and ( $M^+$ ) in equations (9 and (10, the metal becomes more active and its tendency toward corrosion is enhanced. But if the potential of a metal is shifted in the same negative (less noble) direction by polarization from an external source of potential, i.e., by an externally imposed shift in the value of  $V$ , the tendency toward corrosion is lessened and the metal cathodically protected.

By the same paradox, note that, on the one hand, noble metals have an inherent chemical resistance to corrosion, on the other hand, the anodic polarization of a metal to a more positive (more noble) potential enhances its corrosion rate.

This paradox must be kept clearly in mind in order to evaluate the effect of a polarization potential, as opposed to a Nernst potential, on the corrosion tendencies of a metal.

### Potentials At Ideal Polarized Electrodes

Finally, consider a type of polarized electrode which has been extensively studied by David C. Grahame and his co-workers, namely, the ideal polarized electrode,<sup>3</sup> i.e., an electrode at which the transfer of electricity between metal and solution is forbidden, so that the interface acts like an electrical condenser. Strictly speaking, the ideal polarized electrode is a mathematical fiction like the ideal gas, but there is one outstanding case in which it can be experimentally realized very closely, viz., at a surface of mercury in the presence of an electrolyte containing no easily reducible cations and within a potential range in which there is no appreciable corrosion of mercury and no appreciable discharge of hydrogen ions (almost 2 volts).

At such an electrode, the oxidation and reduction processes called for by Faraday's Law are chemically inhibited. Consequently, the Nernst equation fails to determine the potential. There is another type of electrochemical equilibrium which determines the electrode potential, namely, the electrostatic equilibrium between the charged layer of ions on the solution side of the interface and the oppositely charged surface layer of the metal. If the solution layer carries a positive charge (i.e. contains an excess of cations), the metal surface will have an excess of



electrons. If the solution layer carries a negative charge (i.e. contains an excess of anions), the metal surface will have a deficiency of electrons. These two layers are referred to as the *electrode double layer*, and they may be considered as the two plates of an electrical condenser, a concept first introduced by Helmholtz in 1879.

An important property of the double layer is its *isoelectric potential*, i.e., the potential at which both layers carry zero charge.<sup>24</sup> For mercury in the presence of the K or Na salts of "capillary inactive" anions ( $F^-$ ,  $CO_3^{2-}$ ,  $OH^-$ ,  $SO_4^{2-}$ ), the isoelectric potential is equal to

$$V_{iso} = -0.20 \text{ volts}$$

referred to the SHE. For mercury the isoelectric potential is also known as the electrocapillary maximum.

The capacity of the double layer can be measured by means of an AC impedance bridge. It is not rigorously a constant, so that the parallel plate condenser model gives only a crude representation of the double layer. The differential capacity  $C$  is defined by the derivative  $dq/dV$  where  $q$  is the surface charge density of the metal. The value of  $C$  varies with the potential  $V$  and with the nature and concentration of the electrolyte within the range 10-100 microfarads per square centimeter. At potentials on the negative (less noble) side of the isoelectric point, values ranging from 16 to 20 microfarads per  $cm^2$  are often observed. The charge of an ideal polarized electrode is determined by the electrode potential and by the capacity of the double layer by means of the equation

$$q = \int_{V_{iso}}^V C dV. \quad (24)$$

The limits specified must be used since  $q = 0$  at the isoelectric point.

Wherever a Faraday's Law effect sets in, the differential capacity  $C$  becomes infinitely large. This type of capacity is called by Grahame a pseudo-capacity. The residual current of polarography is a non-Faraday current caused by the charging of the double layer at a growing mercury drop.

### Summary

In the foregoing pages, a study of the laws governing the potentials of electrodes under a variety of conditions is attempted: electrodes at equilibrium (reversible Nernst potential) in both standard and non-standard states (Electrochemical Law of Mass Action). The conventions and nomenclature of electrode potentials are reviewed. The main features of non-equilibrium (polarized) electrodes are discussed, with a particular study of the fundamentals of cathodic protection. A brief survey of the ideal polarized electrode is given.

### References

1. J. Willard Gibbs, *Collected Works, Volume I, Thermodynamics*, Longmans Green, New York, 1931, page 429. The words quoted here are taken from a letter written to Professor Wilder D. Bancroft of Cornell University in 1899.
2. Samuel Glasstone, *Introduction to Electrochemistry*, Van Nostrand, New York, 1942, pp. 189-193.
3. David C. Grahame, *Chem. Reviews*, **41**, 441-501 (1947).

4. Walther Nernst, *Zs. physik. Chemie*, **2**, 613, **4**, 129 (1889); also *Theoretical Chemistry*, translated from the 7th German edition, Macmillan, London, 1916, pp. 799-800.
5. Wendell M. Latimer, *Oxidation Potentials*, 2nd edition, Prentice Hall, New York, 1952.
6. Duncan A. MacInnes, *Principles of Electrochemistry*, Reinhold, New York, 1939, Chapter 15.
7. Abegg, Auerbach and Luther. *Abhandl. Bunsengesell.*, No. 5, Halle, 1911.
8. G. Kortüm and J. O'M Bockris, *Textbook of Electrochemistry*, Elsevier, Amsterdam, 1951, Volume I, pp. 251-255.
9. H. J. Creighton and W. A. Koehler, *Principles and Applications of Electrochemistry*, Wiley, New York, 1935, Vol. I, pp. 192-208, Vol. II, pp. 36-37.
10. C. L. Mantell, *Industrial Electrochemistry*, McGraw Hill, New York, 1940, pp. 52-60.
11. I. M. Kolthoff and James J. Lingane, *Polarography*, 2nd edition, Interscience, New York, 1952, Vol. I, p. 190.
12. G. P. Harnwell, *Principles of Electricity and Electromagnetism*, McGraw Hill, New York, 1938, p. 177.
13. Herbert H. Uhlig, *Corrosion Handbook*, Wiley, New York, 1948, pp. 1134-1137.
- 13a. John H. Perry, *Chemical Engineers' Handbook*, McGraw Hill, New York, 1934, pp. 2315-2318.
14. G. N. Lewis, *J. Amer. Chem. Soc.*, **35**, 1 (1913).
15. G. N. Lewis and Merle Randall, *Thermodynamics*, McGraw Hill, New York, 1923, Chapter XXX.
16. F. Daniels, J. H. Mathews, J. W. Williams, *Experimental Physical Chemistry*, 4th edition, McGraw Hill, New York, 1949, page 194.
17. Reference 15, page 402.
18. Reference 13, page 483.
19. F. P. Bowden and J. N. Agar, *Ann. Reports Chem. Soc. (London)*, **35**, 90 (1938).
20. J. Tafel, *Zs. physik. Chemie*, **50**, 641 (1905).
21. A. J. deBethune, *J. Amer. Chem. Soc.*, **71**, 1556 (1949).
22. J. O'M Bockris, *J. Electrochem. Soc.*, **98**, 153C (1951).
23. Robert Pope, in the *Corrosion Handbook* (Reference 13), pp. 935-936.
24. Reference 11, page 136.

### DISCUSSION

#### Questions by Lee H. Elizer, Charlotte, N. C.:

1. Is there a pH drop of the electrolyte as iron goes into solution? The following experience prompts this question: The pH of fresh condensate from a heater was 8.4; the specific conductance was 30 micromhos. The heater consisted of copper tubes and an iron header in which the condensate collected. There was a warm spell and the heater was not used for 8 days at which time the iron header was observed to be leaking condensate. The pH of this condensate was 5.3; the specific conductance was 200 micromhos and there was much suspended magnetic iron oxide. The boiler carries a sulfite reserve of 15 ppm and enough morpholine is added to control pH of condensate between 7.5 and 8.5.

This same pH drop and increase in conductivity was found in a new heater after 5 days of idleness and no leaks of air into the system could be detected.

2. Can corrosion be minimized by keeping the conductivity of the electrolyte low? I thought the corrosion could be minimized until I ran into the following experience. Now I am confused. An iron nut was extracted with distilled water in a Soxhlet apparatus for 4 hours. The distilled water had a specific conductance of 210 micromhos and a pH of 6.5 at the points of contact of the iron nut with the cellulose thimble rust spots developed which were

apparent on the outside of the thimble. The nut lost 0.02 percent of its weight. The distilled water was discolored with iron oxide.

Thank you for your fine paper.

#### Replies by Andre J. deBethune:

1. This looks like a case of galvanic corrosion between the copper tubes (cathodes) and the iron header (anode) with consequent corrosion of the anode. Most ferrous and ferric salts are weakly acidic by hydrolysis, e.g., ferric ion has a first hydrogen ionization constant of  $4 \times 10^{-3}$  (for the reaction  $\text{Fe}^{3+} + \text{H}_2\text{O} = \text{Fe}(\text{OH})^{2+} + \text{H}^+$ , this is stronger than acetic acid). This could account for the observed drop in pH. A decrease in the copper-to-iron area ratio might improve the picture.

2. Corrosion can certainly be minimized, other things being equal, by lowering the conductivity of the electrolyte. However, I am not sure whether 210 micromhos is low enough. The effect you observed seems to be a case of oxygen concentration cell corrosion, in which the oxygen acts as the corroding agent, but, by a curious paradox, the corroding action is carried galvanically to those points on the metal where the access of oxygen is blocked (anodes in the oxygen concentration cell).

Those areas to which oxygen is freely accessible act as cathodes in the concentration cell and are cathodically protected. If the anodes are small and the cathodes large, the corrosion of the anodes is likely to be enhanced.

#### A Technical Note

## Corrosive Attack by Acidic Decomposition Products Evolved by Paints While Drying\*

IN 1951, an investigation was begun to find the reason for the corrosion of the metal parts of helicopter blades stored in closed, painted, wooden crates. The blades were constructed mostly of wood with various steel parts such as leading edges and spar tubes. Steel surfaces were cadmium plated prior to painting; the lids of the weight boxes (small cavities in the blades to hold balancing weights) were constructed from magnesium alloys. The crate lid fittings were of zinc plated steel. On the blades, one coat of zinc chromate primer and one or two coats of sea blue enamel were used. The blades were packed in a large crate cushioned in natural rubber latex pads. Both the interior and exterior of the crate was coated with an aluminum pigmented type of paint.

Chemical and infrared analyses of the scrapings taken from the corroded parts showed the presence of the lower molecular weight fatty acid salts of zinc, cadmium and magnesium. The metallic portion of these salts corresponded to the base metal or platings of the areas from which the scrapings were removed. It was suspected that volatile organic contaminants which might have been liberated in the unvented box caused the corrosion. A literature search revealed that it was possible to obtain volatile acids from polymerization and oxidation reactions taking place in the normal drying process of a paint film.

As test, a series of pint jars was used in which individual zinc, cadmium and magnesium metal specimens were inserted and exposed to blocks painted with the same paint used on the interior of the box. Some blocks were freshly painted; others painted and then dried thoroughly; others were cut from the packing case. The control blocks were of unpainted, plain wood. The jars were assembled in two sets, one set contained distilled water, the other set did not. Both sets were sealed and placed in an oven at 37.7 degrees C for two weeks. At the end of this time the jars were removed, cooled, and disassembled.

A white powdered substance appeared on all of the metal specimens (zinc, cadmium and magnesium) exposed to the wood blocks that were coated with the fresh aluminum paint used on the interior and exterior of the crate. This was true also with the fresh varnish used as the base in the aluminum paint. Chemical and infrared analyses of these white powdered corrosion products established their similarity with the scrapings obtained from the helicopter blades. Specimens in the other jars did not contain the white corrosion product.

Infrared analyses were conducted by Philip Fischer.

As a result of the tests, the following methods for alleviating corrosion were suggested:

1. Helicopter blades could be packed in unpainted wood boxes;
2. The crates could be sprayed with a short-drying lacquer type coating which eliminates oxidation and polymerization reactions of drying oils, and which provides a plastic type coating.
3. Finally, the interior of the crates could be coated with the aluminum paint now used, providing a sufficient length of time is allowed for thorough drying before loading and closing.

\* Based on work performed by Alfred L. Glass and David L. Dorfman at Aeronautical Materials Laboratory, Naval Air Experimental Station, Philadelphia Naval Base.

The opinions or assertions contained herein are the private ones of the investigators and are not to be construed as official or reflecting views of the Navy Department or the naval service at large.

# Resistance of Aluminum Alloys To Weathering\*

By C. J. WALTON, D. O. SPROWLS  
and J. A. NOCK, JR.

THE IMPORTANCE of information on the atmospheric weathering characteristics of aluminum alloy products is commensurate with the large tonnage of these products being used in the building and construction industries. This usage is attributable to the good resistance to corrosion of aluminum alloys complemented by other desirable characteristics, such as light weight, adequate strength and good formability. Also, the pleasing appearance of aluminum alloy products and their adaptability for various decorative coatings provide interesting architectural effects (Figure 1).

A large number of aluminum alloys is available in the form of various wrought and cast products. Alloy compositions and metallurgical treatments are selected in order to secure the best combination of properties for specific applications. Although physical properties, such as density, hardness, strength and ductility can be established with sufficient accuracy to enable the engineer to use the data in mathematical expressions concerning design, it is impracticable, if not impossible, to use such expressions with regard to the resistance to atmospheric weathering of metals and alloys. This characteristic must be stated in relative terms, because the corrosivity of atmospheric conditions varies markedly from one locality to another and even within a given area.

Laboratory tests, such as the salt spray test, may provide useful information of a comparative nature but are not adequate for predicting the actual performance in outdoor exposures. In fact, such accelerated corrosion tests have been found to exaggerate differences among alloys that are negligible as judged by actual exposure of specimens to the weather. There is no reliable laboratory test that duplicates the effects of long time atmospheric exposures.

The Aluminum Research Laboratories of Aluminum Company of America has, during the past 25 years, exposed many thousands of specimens to the atmosphere in many localities in this country and at several places outside this country. The magnitude of the coverage may be appreciated from the fact that one of the initial comprehensive investigations, started 20 years ago, involved exposure of about 25,000 individual test specimens. Tests which formed the basis of several earlier publications<sup>1, 2, 3</sup> and subsequent investigations on newer alloys are



Figure 1—View during construction of Alcoa Office Building, Pittsburgh, Pa., showing the pyramidal facets made by aluminum alloy panels and windows which sheath this new thirty story building. This innovation is a reflection of considerable background of experience, such as that obtained from the ornamental church steeple (foreground) composed of aluminum alloy castings (alloy 43), in service since about 1926.

## Abstract

Extensive data selected from tests of many thousands of specimens of aluminum alloys, exposed in various natural atmospheres for periods as long as 20 years, are presented graphically. These data provide comprehensive coverage of the resistance to weathering of outstanding types of wrought and cast aluminum alloys, with particular emphasis on alloys used in architectural and structural applications. Effects of weathering were evaluated by measurement of change in strength and depth of attack of specimens exposed for periods up to 20 years in natural atmospheres and for as long as 52 years in actual service.

Aluminum alloys have been evaluated in a sufficient number of different types of atmospheres at widely separated geographic locations to predict with reasonable assurance the performance expected under most conditions normally encountered. The corrosion of aluminum alloys, both wrought and cast, exhibits a "self stopping" characteristic; that is, the rate of attack after an initial exposure period of about one to two years decreases to a very low value, generally to less than 0.2 mil per year. The aluminum alloys displayed high resistance to corrosion and although some differences were noted, these differences often were subordinate to other characteristics of interest, such as strength, formability, appearance and cost.

now sufficiently inclusive to demonstrate convincingly the atmospheric weathering characteristics of aluminum alloys when subjected to a wide variety of conditions, including industrial, seacoast and tropical environments. Corrosive conditions within or immediately adjacent to chemical or petrochemical plants, etc., are unique and have been found worthy of separate consideration.<sup>4</sup>

\*A paper presented at the Ninth Annual Conference, National Association of Corrosion Engineers, Chicago, Ill., March 16-20, 1953.





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**J. A. NOCK, JR.**—Graduated from Pennsylvania State College in 1923 with a BS degree in Electrochemical Engineering. Since then he has been employed by Aluminum Company of America in research work, particularly in development of wrought alloys presently in use. His work has also included the development of fabricating practices and thermal treatments for aluminum alloys and he has presented a number of technical papers covering these subjects. A number of patents have been granted to him. His present position is Assistant Chief of Physical Metallurgy Division of Aluminum Research Laboratories.

### Materials

This paper presents corrosion data on a variety of Alcoa wrought and cast aluminum alloys (Tables I and II), with emphasis given to those alloys commonly employed in building and architectural applications. Most of the products exposed were from routine plant production, but some laboratory fabricated lots were used also. None of the items was given any special surface treatments. The test specimens were simply solvent cleaned and exposed without benefit of any protective coatings.

### Exposure Stations

The majority of the test specimens have been exposed at two basic weathering stations maintained by Alcoa: a seacoast station (Figure 2) 300 feet from the Atlantic Ocean at Point Judith, Rhode Island, and an industrial atmosphere station located on the roof of the Aluminum Research Laboratory at New Kensington,

Pennsylvania. Correlation of the relative corrosivity of conditions at these basic stations with those elsewhere was obtained by the exposure of duplicate sets of specimens at several auxiliary Alcoa exposure stations. In addition, specimens were exposed at Kure Beach, N. C., through the courtesy of the International Nickel Co. and at Miami Beach, Florida by arrangement with the South Florida Test Service. Cooperative tests sponsored by the American Society of Testing Materials<sup>2</sup> have provided valuable data on the performance of several aluminum alloys when exposed for 10 years to the atmosphere at nine weathering stations of ASTM. The location and characteristics of these exposure stations are described in Tables III and IV.

### Methods of Evaluation

Weight loss measurements or average penetration of attack data based on loss in weight, although useful for metals, such as steel, zinc and copper, which undergo relatively uniform overall reduction in thickness, have been found<sup>2</sup> less informative for aluminum alloys. The thin protective oxide film, characteristic of aluminum alloys, limits corrosion to a relatively few points so that some, if not most of the original surface of the metal generally remains intact even after many years of weathering. Experience has shown that the most informative and practicable methods for evaluating the effect of weathering are by

- changes in tensile strength and
- determination of actual depth of attack.

The former method is a more sensitive criterion because it selects the cross section that has weathered to the greatest degree. The latter method provides a more realistic measure of the rate of penetration. Both methods have engineering significance.

All tensile tests reported herein were conducted using standard ASTM tension specimens.<sup>5</sup> Wrought alloys were commonly exposed to the weather as machined tension specimens, usually 0.064-inch thick.

**TABLE I**  
Composition and Typical Tensile Properties of Wrought Aluminum Alloys Under Discussion

ALLOY	NOMINAL COMPOSITION—Percent						TYPICAL TENSILE PROPERTIES <sup>4</sup>				
	Cu	Si	Mn	Mg	Zn	Cr	Temper	Tensile Strength PSI	Yield Strength (Offset = 0.2%) PSI	Sheet Specimen 0.064" Thick	Round Specimen 0.50" Dia.
2S.....	.....	.....	99.0	% Minimum Aluminum			H14	17500	16000	9	20
3S.....	.....	.....	1.2	.....	.....	.....	H14	21500	19000	8	16
Alclad 3S <sup>1</sup> .....	.....	.....	1.2	.....	.....	.....	H14	21500	19000	8	16
4S.....	.....	.....	1.2	1.0	.....	.....	H34	34000	27000	9	12
Alclad 4S <sup>1</sup> .....	.....	.....	1.2	1.0	.....	.....	H34	34000	27000	9	12
50S.....	.....	.....	.....	1.4	.....	.....	H34	27500	24000	8	.....
52S.....	.....	.....	.....	2.5	.....	0.25	H34	37000	31000	10	14
A54S.....	.....	.....	.....	3.5	.....	0.25	H34	40000	33000	13	.....
53S.....	.....	0.7	.....	1.3	.....	0.25	T6	37000	32000	.....	13
61S.....	0.25	0.6	.....	1.0	.....	0.25	T6	45000	40000	12	17
62S.....	0.25	0.6	.....	1.0	.....	.....	T6	45000	40000	.....	17
63S.....	.....	0.4	.....	0.7	.....	.....	T5	27000	21000	12	.....
Alclad 14S <sup>3</sup> .....	4.4	0.8	0.8	0.4	.....	.....	T6	68000	60000	11	.....
Alclad 17S <sup>3</sup> .....	4.0	.....	0.5	0.5	.....	.....	T3	56000	33000	18	.....
Alclad 24S <sup>3</sup> .....	4.5	.....	0.6	1.5	.....	.....	T3	64000	44000	18	.....
Alclad 75S <sup>4</sup> .....	1.6	.....	.....	2.5	5.6	0.3	T6	76000	67000	11	.....

<sup>1</sup> Alclad coating is alloy 72S (1% zinc).

<sup>2</sup> Alclad coating is high purity aluminum.

<sup>3</sup> Alclad coating is alloy 53S.

<sup>4</sup> "Alcoa Aluminum and Its Alloys," Aluminum Company of America, 1950.

In some cases, panels were exposed and tension specimens were machined from them after different periods of weathering. Casting alloys were evaluated in the form of round tension bars: 0.500-inch in diameter for sand castings and 0.250-inch in diameter for die castings. The effect of weathering on the strength of all materials was established by comparing the tensile strengths—based on the original cross sectional areas—of the exposed specimens with those of storage specimens tested concurrently.

Depth of attack was determined metallographically. Several cross sections including the most conspicuous areas of attack were polished and the depth of attack measured (X100) using a microscope fitted with a Filar micrometer eye piece. For each lot of material after each exposure period, the maximum depth of attack observed was measured. In addition, a number of sites of attack were measured in order to establish the average depth of penetration. In substantially all cases, the original surface was sufficiently intact (Figure 5) to provide a reference for accurate measurement of depth of attack. It should be appreciated that this latter value is the mean of the individual sites of attack and does not integrate the large area over which no attack or insignificant attack had occurred. The penetration, as estimated from these measure-

ments, will always be considerably greater than that calculated from weight losses.<sup>2</sup>

### Calibration at Atmospheric Exposure Stations

The geographical location, as pointed out by Dix and Mears,<sup>2</sup> is often of less importance in determining the corrosivity of the environment than are other factors, such as direction of prevailing winds, type

TABLE II  
Composition and Typical Tensile Properties of Aluminum Casting Alloys Under Discussion

ALLOY	NOMINAL COMPOSITIONS—Percent					TYPICAL TENSILE PROPERTIES <sup>3</sup>			
	Cu	Si	Mn	Mg	Zn	Temper	Tensile Strength PSI	Yield Strength (Offset = 0.2 %) PSI	Elongation—% in 2" Round Specimens
<b>Sand Casting Alloys:</b>									
43.....		5.0				As-cast	19000	8000	8.0
12.....	8.0					As-cast	22000	14000	2.0
112.....	7.0				1.7	As-cast	24000	15000	1.5
195.....	4.5	0.8				T4	32000	16000	8.5
195.....	4.5	0.8				T6	36000	24000	5.0
214.....				3.8		As-cast	25000	12000	9.0
B214.....		1.8		3.8		As-cast	20000	13000	2.0
220.....				10.0		T4	46000	25000	14.0
356.....		7.0		0.3		T6	33000	24000	3.5
406.....			2.0			As-cast	19000	9000	12.0
<b>Die Casting Alloys:</b>									
43.....		5.0				As-cast <sup>2</sup>	30000	16000	9.0
13.....		12.0				As-cast <sup>2</sup>	39000	21000	2.0
A13 <sup>1</sup> .....		12.0				As-cast <sup>2</sup>	35000	16000	3.5
85.....	4.0	5.0				As-cast <sup>2</sup>	40000	24000	5.0
380.....	3.5	9.0				As-cast <sup>2</sup>	45000	26000	2.0
A380 <sup>1</sup> .....	3.5	9.0				As-cast <sup>2</sup>	46000	25000	3.0
384.....	3.8	12.0				As-cast <sup>2</sup>	46000	27000	1.0
360.....		9.5		0.5		As-cast <sup>2</sup>	44000	27000	3.0
A360 <sup>1</sup> .....		9.5		0.5		As-cast <sup>2</sup>	41000	23000	5.0
218.....				8.0		As-cast <sup>2</sup>	45000	27000	8.0

<sup>1</sup> Prefix "A" indicates that alloy has impurities, notably iron, controlled to closer limits.

<sup>2</sup> Test bars produced on a cold chamber (high-pressure) die-casting machine.

<sup>3</sup> "Alcoa Aluminum and Its Alloys," Aluminum Company of America, 1950.

TABLE III—Description of Various Seacoast Exposure Stations

LOCATION	Climatic Zone	Distance From Ocean or Bay	Type of Shore	Direction of Prevailing Winds	Remarks	Station Operated By
Kure Beach, N. C.....	Temperate	80 ft.	Sandy	From Ocean	Sea rough, considerable salt mist.	International Nickel Co.
Pitcairn Island, British Oceania.....	Sub-Tropical	150 ft.	Rocky	From Ocean	Sea rough, considerable salt mist.	Alcoa
La Jolla, Cal.....	Temperate	"Several hundred feet"	Rocky	From Ocean	Sea rough, frequent fogs, little rain to wash specimens.	ASTM
Point Judith, R. I.....	Temperate	300 ft.	Stony	From Ocean	Sea rough, considerable salt mist and fogs.	Alcoa
Key West, Florida.....	Sub-Tropical	"Close to ocean"	Sandy	Across Island	Station on leeward side of island.	ASTM
Miami Beach, Fla.....	Sub-Tropical	300 ft.	Sandy	From Ocean	Warm, humid without fogs.	South Florida Test Service
Sandy Hook, N. J.....	Temperate	300 ft.	Sandy	From Bay	Station at tip of Hook jutting into bay.	ASTM
Oakland, Cal.....	Temperate	1 mile		From Bay	On roof of warehouse, seasonal fogs.	Alcoa
Georgetown, British Guiana.....	Tropical	1.5 miles		From Ocean	On low building by Demerara River. Hot, humid.	Alcoa

TABLE IV—Description of Various Industrial and Inland Atmospheric Exposure Stations

LOCATION	Type of Environment	Predominant Fuel Used	Remarks	Station Operated By
New Kensington, Pa.....	Industrial	Bituminous Coal	Located on roof of Aluminum Research Laboratories, exhaust from Analytical Laboratory hoods add to the severity of the atmosphere.	Alcoa
Pittsburgh, Pa.....	Industrial	Bituminous Coal	Racks were on Brunot's Island, 3 miles below Golden Triangle. Exposures made before smoke control, when specimens were subjected to atmosphere highly contaminated by heavy industries.	ASTM
Altoona, Pa.....	Industrial	Bituminous Coal	Racks on roof of building in the Pennsylvania Railroad yards. The atmosphere contained unusually large amounts of smoke and gases from the busy yards and shops.	ASTM
St. Louis, Mo.....	Industrial	Bituminous Coal	Racks on two-story building in heart of city. Exposures made before smoke control when atmosphere contained appreciable amounts of sulphur dioxide.	Alcoa
New York, N. Y.....	Industrial	Oil and Anthracite Coal	Racks on roof of Bell Telephone Laboratories on West Street. Atmosphere contains much smoke and gases from fuels used in this metropolitan area.	ASTM
Edgewater, N. J.....	Industrial	Oil and Anthracite Coal	Racks on roof of Alcoa plant on Hudson River, across from New York City. Specimens subjected to fumes from plant and other waste gases associated with this highly industrial area.	Alcoa
Rochester, N. Y.....	Industrial	Bituminous Coal	Racks in gorge of Genesee River, below a water fall; high humidity, with waste gases from nearby factories.	ASTM
State College, Pa.....	Rural		Clean, rural district—no industrial contamination.	ASTM
Phoenix, Arizona.....	Rural		Hot and dry; semi-arid.	ASTM

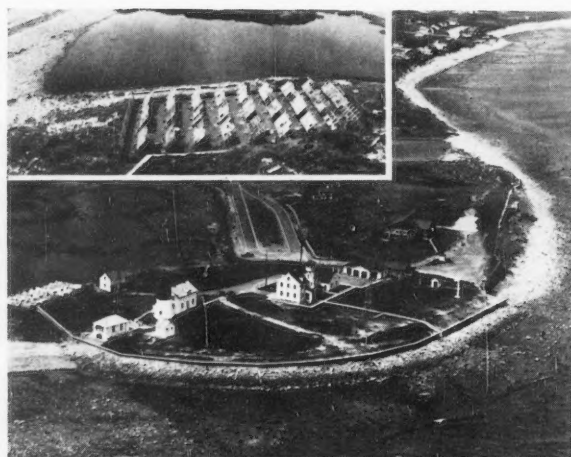


Figure 2—Aerial view and close-up (inset) of Alcoa's seacoast exposure station at Point Judith, R. I. The station is located on a stony beach about 300 feet from the water's edge and it faces the prevailing winds from the ocean. Corrosion conditions here are severe indeed. At this and all of the other Alcoa exposure stations the test specimens were inclined at an angle of 45 degrees, facing south.—(Aerial photo—courtesy of Providence [R. I.] Sunday Journal.)

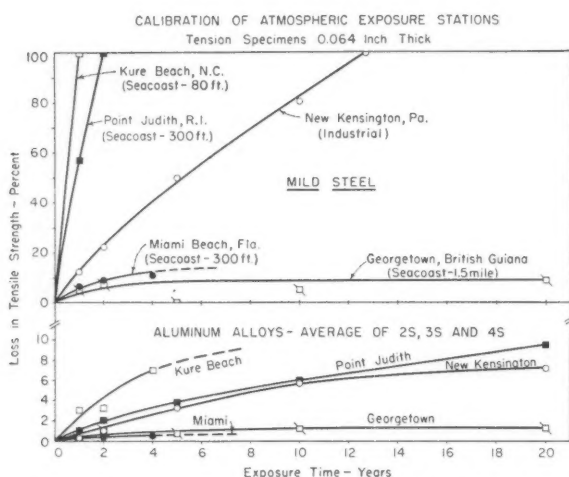


Figure 3—Graph illustrating the relative severity of several exposure stations employed by the Aluminum Research Laboratories using losses in tensile strength of 0.064-inch thick mild steel (0.09% carbon, 0.07% copper) as the criterion. The aluminum alloys (also 0.064-inch thick) rate the stations in essentially the same order as does mild steel. The corrosivity of a seacoast atmosphere varies not only with distance from the ocean, but also with other inherent location factors.

of topography, frequency of precipitation and proximity to bodies of water or industrial plants. The corrosivity of the atmosphere may vary as much or more within a given geographic region than between widely separated locations. It is imperative, therefore, to calibrate the severity of the conditions at each atmospheric weathering station. Conditions at Alcoa's basic seacoast station at Point Judith, Rhode Island and the industrial atmosphere station at New Kensington, Pa. were calibrated by determining their effects on veteran metals, such as steel and copper and by comparing the corrosivity of atmospheric

# CALIBRATION OF ATMOSPHERIC EXPOSURE STATIONS

Tension Specimens 0.035" Thick

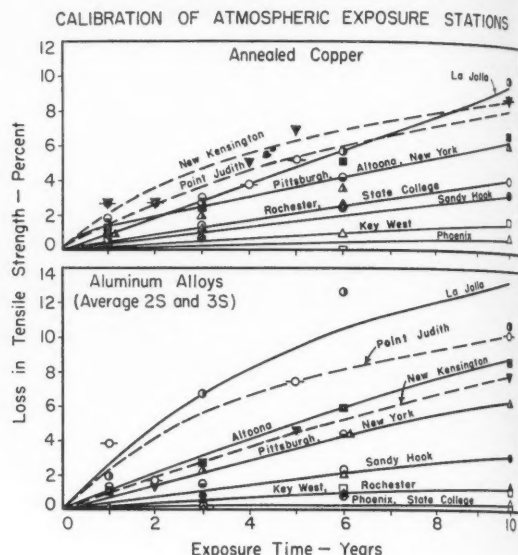


Figure 4—Data obtained on aluminum alloys and copper were used to indicate the relative severity of the atmospheric conditions at the two Alcoa exposure stations at New Kensington (industrial) and Point Judith (seacoast) and the nine different ASTM stations. This comparison was made possible, even though different thicknesses of material were employed at the Alcoa stations (0.064-inch) and the ASTM stations (0.035-inch), by the conversion of the percent losses in tensile strength for 0.064-inch thickness to the equivalent percent loss for 0.035-inch thickness. The curves representing Point Judith and New Kensington were drawn as broken lines indicating that these data were calculated.

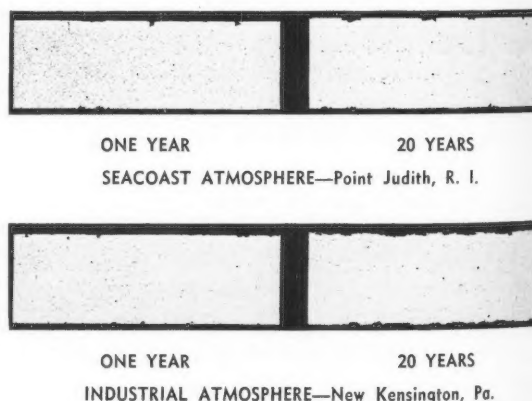


Figure 5—Micrographs of full cross sections of 0.064-inch thick sheet of alloy 3S after exposures indicated. Note that the corrosion develops at isolated spots, slowly spreads to new sites but is not appreciably deeper after 20 years than after one year. This pattern is typical for other corrosion resistant aluminum alloys, such as 4S, 52S, 61S.

conditions at these stations with those at many widely scattered localities.

The relative severity of corrosive attack at the seacoast station at Point Judith and at the industrial one at New Kensington is indicated in Figures 3, 4 and 24. It is obvious that corrosive conditions at the Point Judith station, 300 feet from the ocean, are very severe indeed, being more corrosive than at most seacoast locations evaluated and almost as severe as those at Kure Beach (80-foot site) and at



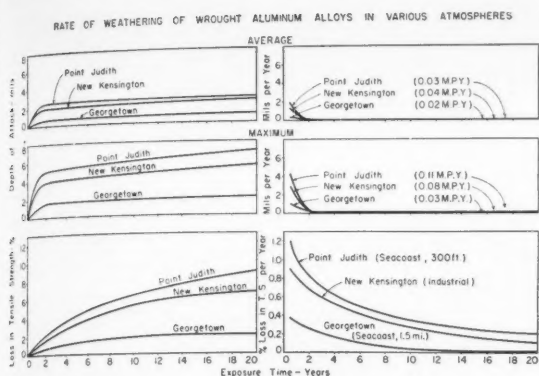


Figure 6—The rate of weathering (curves at right) based on the average performance of alloys 2S, 3S and 4S exposed at Georgetown and on the eight wrought alloys included in Figures 7 to 10 illustrate the "self-stopping" nature of the corrosion of aluminum alloys. A comparison of the abrupt reduction in rate of penetration (top) with the more gradual reduction of loss in tensile strength (bottom) indicates that although the penetration of corrosion at local sites has been stifled, corrosion is still proceeding elsewhere but at a reduced rate.

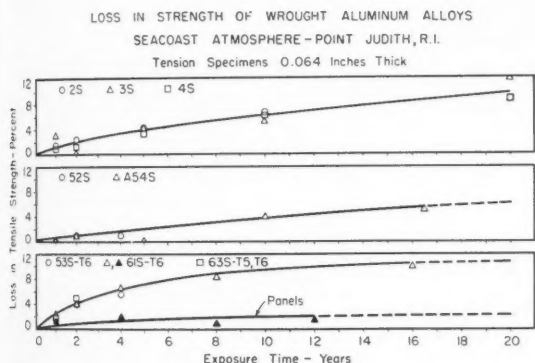


Figure 7—The curve for each family of aluminum alloys is the mean of individual curves that had been drawn for each alloy. (Curves for Figures 8, 9, 10 were drawn on same basis.) The conformity of the data to these average curves indicates that the resistance to corrosion is similar for the alloys in each group. The high resistance to this severe seacoast atmosphere is indicated by the small losses in strength in exposure periods of 16 to 20 years.

La Jolla, California. The gratifying significance of this is that data obtained at the Point Judith station can be used with confidence to indicate the expected performance of metals, especially aluminum alloys, at most seacoast environments, including island exposures. For example, an incidental opportunity resulted in exposure of various metals for four years on Pitcairn Island. Aluminum alloys were not affected any more at this location, about 150 feet from ocean, than at Point Judith.

The corrosivity of the atmosphere at New Kensington is about as severe as that at Altoona, New York and Pittsburgh (before smoke control) and generally more severe than the atmosphere at other inland areas evaluated. This suggests that data obtained from exposures at New Kensington can be used to indicate conservatively the resistance of aluminum alloys to the atmosphere in most industrialized areas and by comparison to atmospheres at substantially all non-industrial (rural, etc.) areas.

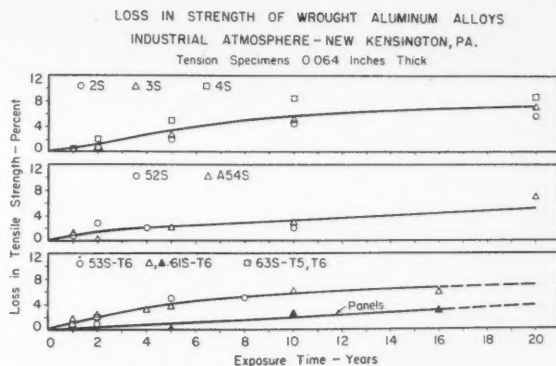
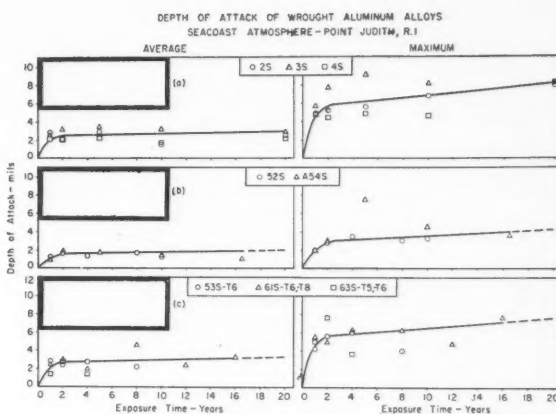


Figure 8—These average curves (determined as per Figure 7) demonstrate that exposures for as long as 20 years in a relatively severe industrial atmosphere had little effect on the structural integrity of the various aluminum alloys.



(a)

(b)

(c)

Figure 9—These average curves (determined as per Figure 7) show that corrosion of all alloys decreases with time and that the attack after as long as 20 years is shallow. Although the differences are small, the aluminum-magnesium alloys (52S, A54S) display their characteristic superiority when exposed to marine environments. Micrographs of typical cross sections of 0.064-inch thick sheet include (a) 3S at 20 years, (b) A54S at 16.5 years, (c) 61S-T6 at 16 years.

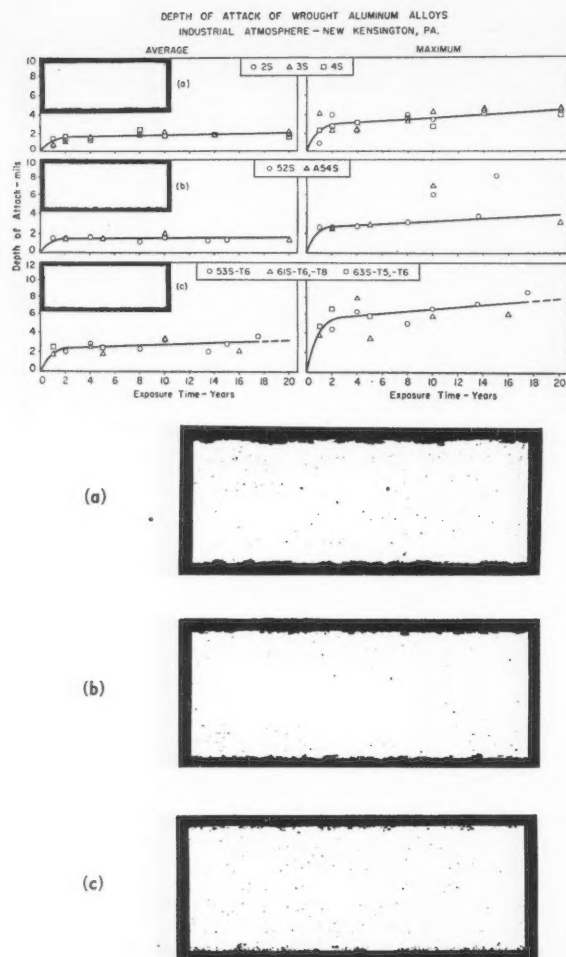


Figure 10—These average curves (determined as per Figure 7) resemble those obtained in exposures at the seacoast (Figure 9). Although the attack was more shallow in this industrial atmosphere than at the seacoast, the surface attack was more widespread as indicated by the micrographs of typical cross sections of 0.064-inch thick sheet of (a) 3S at 20 years, (b) A54S at 20 years and (c) 61S-T6 at 16 years.

#### Rate of Weathering

The outstanding characteristic apparent from the graphical presentation of the corrosion data (Figures 7 to 23) is that the rate of weathering for wrought aluminum alloys and for cast aluminum alloys decreases with time. This decrease in rate of attack (Figure 6) is demonstrated both by depth of attack data and by tensile test data. The decrease in rate of penetration of corrosion is the most striking. The attack penetrates, at isolated spots, at an initial rate of about 4 mils per year (Figure 6); but this rate rapidly decreases so that after one or two years the maximum rate does not exceed about 0.11 mil per year for severe seacoast conditions (Point Judith) and may be as low as 0.03 mil per year for less severe atmospheres.

The rate of weathering, as judged by changes in tensile strength (Figure 6), also decreases with time but not as sharply as it does when judged by the depth of attack. Since tensile strength is a function of the cross sectional area of the test coupon, any

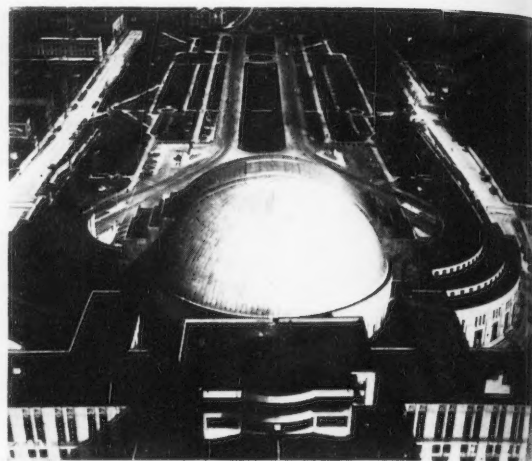


Figure 11—Aerial view of Cincinnati Union Terminal, Cincinnati, Ohio (erected in 1932), showing the large dome-shaped roof sheathed in 1946 with bare aluminum alloy 3S.

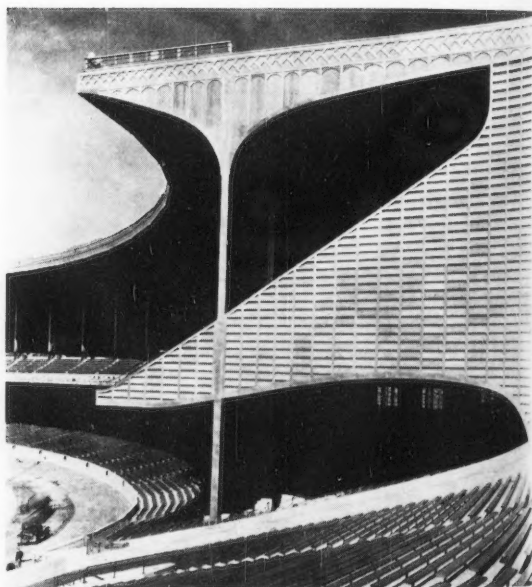


Figure 12—Municipal Stadium, Cleveland, Ohio. Erected in 1931, using 70 tons of aluminum alloys for louvers, flashing or siding, ceilings of marquee roofs and score board. In 1946, after 15 years' service, a sample of alloy 4S-H34 siding 0.032-inch thick was examined in cross section and the metal found to be in an excellent state of preservation (Figure 24).

significant change in tensile strength reflects a decrease in cross sectional area resulting from corrosion. The differences in slopes of the curves in Figure 6 indicate that although corrosion at local sites seems to stop after one or two years' weathering, new sites of attack develop. Thus, the tendency under conditions of atmospheric weathering is for attack to proceed laterally (Figure 5) along the surface rather than to become progressively deeper. The decreased rate of attack as shown by tensile tests also indicates that corrosion over the entire surface diminishes with time. The products of corrosion form a protective film to stifle further attack.

This tendency for the corrosion of aluminum alloys to decrease to a very low rate has been observed in other environments as well as the atmosphere and has been referred to as a "self-stopping" or "self-limiting" effect. Appreciation of this desirable characteristic will dispel unnecessary concern one might otherwise have over some initial surface attack.

### Wrought Aluminum Alloys

The family of wrought aluminum alloys under discussion (Table I) has a high inherent resistance to weathering. Exposures for as long as 20 years to relatively severe industrial and seacoast atmospheres have resulted in shallow attack, with corrosion proceeding at a low rate (Figure 6). These extended exposures have caused only small losses in tensile strength of 0.064-inch thick materials. Although the data were obtained primarily on sheet, other tests have shown that equally favorable results are obtained for these alloys in the form of other products, such as plate, extruded sections, rolled sections and tubes.

It is noteworthy that these aluminum alloys (Figures 7 through 10) possess a high resistance to corrosion, with only small differences existing among them. Final choice, therefore, is usually based on other requirements, such as strength, formability, weldability, appearance and economy. The various alloys are discussed in this light.

### Strain Hardenable Alloys

The strength of pure aluminum and of aluminum alloys containing manganese and magnesium alone or in combination is determined by the degree of strain hardening present. In general, these alloys do not show any real difference in weathering between materials in the annealed temper and that in the strain hardened temper. In fact, the data in Figures 7 to 10 were obtained from materials in both the annealed and strain hardened tempers.

Aluminum alloys 2S, 3S and 4S have essentially the same high resistance to weathering. Alloy 3S (1.2% Mn) has been used widely in building applications because it is stronger than alloy 2S and equally formable. Alloy 4S (1.2% Mn, 1.0% Mg) is used where somewhat greater strength is required. These alloys have performed very well under service conditions (Figures 11 and 12) and are playing an important role in the modern trend toward use of corrosion resistant metals for the outer surfaces of various types of buildings (Figure 13).

Aluminum alloys with increasing amounts of magnesium, within a maximum value yet unresolved, provide a group of alloys with a resistance to corrosion at least as good as the preceding set of alloys in industrial atmospheres and with somewhat superior performance in seacoast environments. Alloy 52S (2.5% Mg, 0.25% Cr) has had wide use, therefore, in marine applications. The recently developed alloy 50S (1.4% Mg) is stronger than 3S and more easily fabricated and formed than 52S, thereby providing a compromise between these two alloys. Limited corrosion tests show that the resistance to corrosion of alloy 50S approximates that of alloys 3S and 52S. Considerable interest has been focused on

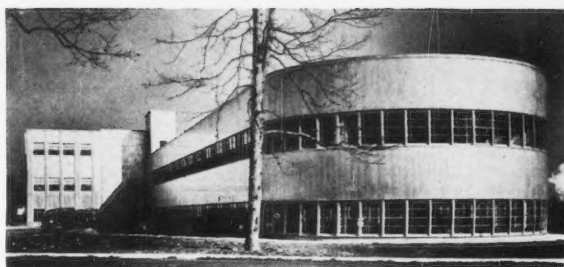


Figure 13—Laboratory of Federal Telephone and Radio Corp. Nutley, New Jersey. Easy to erect insulated panels of aluminum alloy 3S form the weathering surface of this unit erected in 1945 and for units subsequently added. Large numbers of windows of extruded aluminum alloy 63S were also employed. In this non-industrialized environment the bare aluminum alloy surfaces will slowly weather to acquire a uniform light gray patina.



Figure 14—The M. Harvey Taylor Bridge erected over the Susquehanna River at Harrisburg, Pa. in 1952 employs more than two miles of aluminum alloy railing with integral lighting standards of aluminum alloys. The use of alloy 61S-T6 for the various components provide high strength and good resistance to weathering, thus eliminating the need for paint protection and maintenance. Sections of railing of unpainted 61S-T6 or 63S-T6 are performing very well in trials being made on the boardwalk at Atlantic City, N. J., and Virginia Beach, Va.

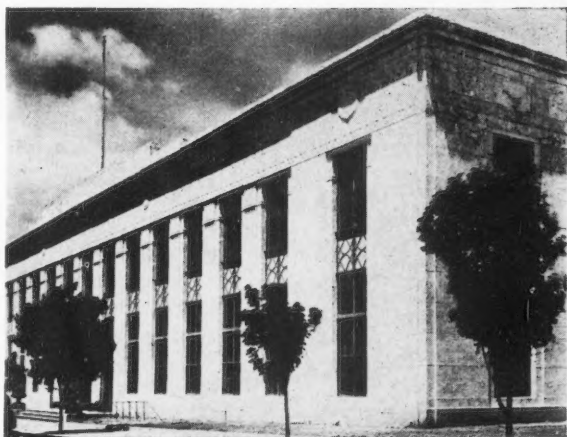


Figure 15—U. S. Government building at Key West, Florida, erected 1932, using windows of extruded aluminum alloy (alloy 43). The seaside conditions prevailing at Key West have had little effect on these unpainted aluminum windows. This photograph, taken in 1944, illustrates the non-staining characteristics of aluminum alloys.



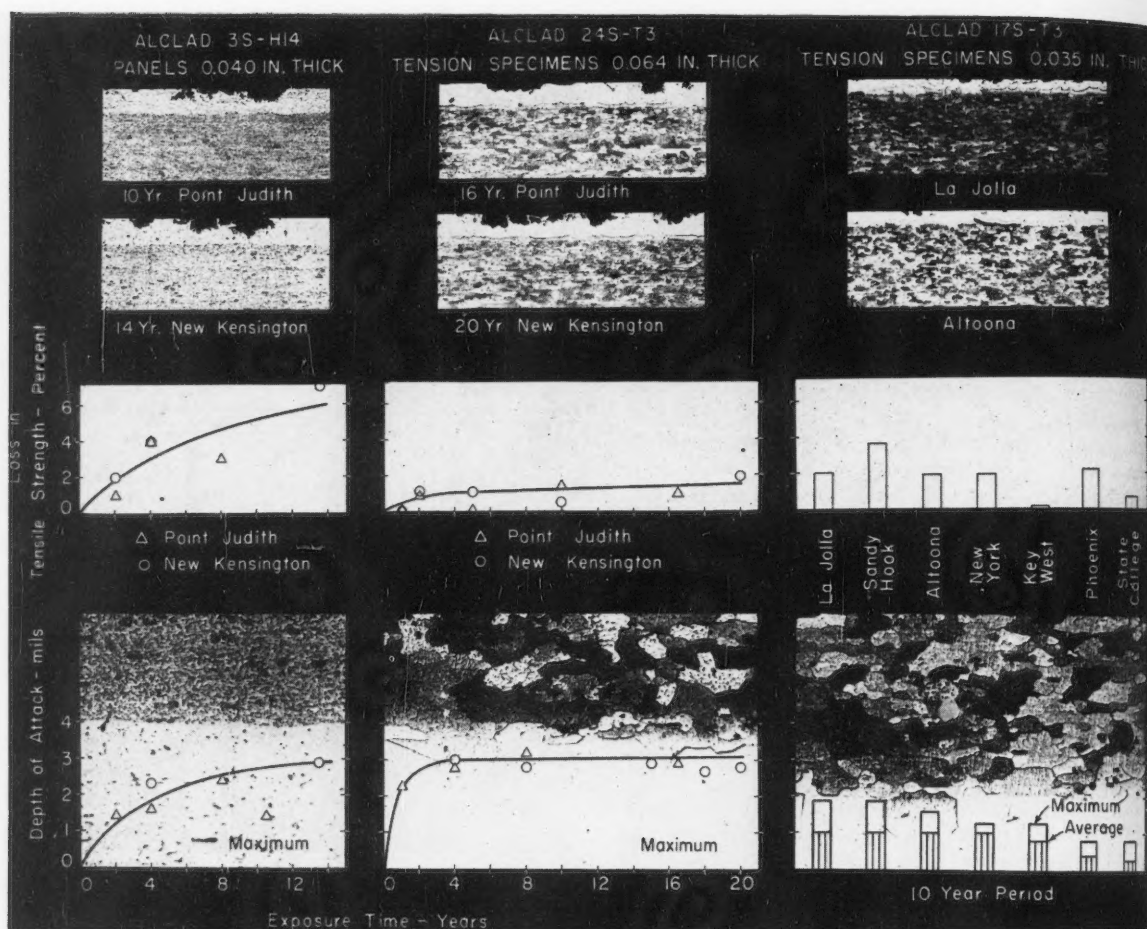


Figure 16—These illustrations show the outstanding resistance to corrosion of alclad products. Note in the bottom graphs, superimposed on unretouched photomicrographs of the alloys, that the maximum attack does not extend beyond the alclad coatings (4.0 mils on Alclad 17S-T3, 3.5 mils on Alclad 24S-T3 and 1.9 mils on Alclad 3S-H14) even after extended exposures in various atmospheres. This is substantiated (top) by micrographs (approx. X77) showing one surface of specimens which had been subjected to the more severe environments. Considerable cladding remains for continued electrochemical protection of core alloys. This protective effect of the alclad coatings is reflected in the small or insignificant losses in tensile strength (Center). Keller's Etch.

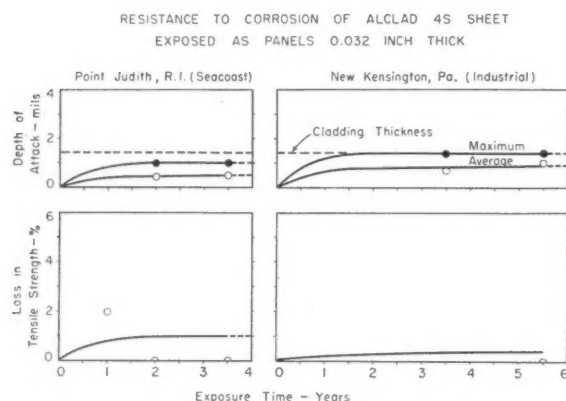


Figure 17—These data after exposures of 3.5 to 5.5 years on thin Alclad 4S are paralleling that procured for other alclad products which had been exposed for much longer periods (Figure 16). As with the preceding alclad products, the attack has been confined to the alclad coating (1.4 mils thick) and these exposures have not caused any really significant losses in strength.

aluminum alloys with magnesium contents in excess of that in 52S, because of their good welding characteristics and relatively high strength when welded. Alloy A54S (3.5% Mg, 0.25% Cr) exhibits these characteristics and has displayed a resistance to weathering almost identical to that of 52S.

#### Heat Treatable Alloys

Aluminum alloys 53S, 61S, 62S and 63S contain magnesium and silicon in the ratio to form the magnesium silicide compound. These alloys respond to heat treatment and artificial aging and can develop greater strengths than the preceding strain hardenable alloys. Some of the alloys contain small amounts of copper or chromium or both. The compositions of these alloys (Table I) were formulated to enhance certain characteristics, such as strength, extrudability and formability, without affecting their resistance to corrosion (Figures 7 through 10).

One of the first of these aluminum-magnesium silicide alloys was 53S. This alloy has been supplemented by alloy 61S, which was developed to obtain

a substantial increase in strength over alloy 53S without effecting any real sacrifice in resistance to most corrosive conditions. This has been substantiated by 16-year exposure data (Figures 7 through 10), thus indicating the suitability of 61S alloy for structural applications, such as power substations, bridge railing and lighting standards (Figure 14), requiring moderately high strength and good resistance to weathering.

Alloy 62S, a recent development, is a modification of 61S with improved formability. Exposures of one year's duration in accelerated corrosion tests and in the atmosphere at New Kensington and Point Judith show that 62S sheet, extruded sections and tubes are performing in a manner comparable to that of 61S.

Alloy 63S contains less magnesium silicide than 61S. This alloy takes a pleasing surface finish and has adequate strength for diverse structural and architectural applications. Millions of aluminum alloy windows used in this post-war period have been made from extruded sections of alloy 63S. They have displayed a high resistance to weathering over an 8-year service period. This, together with the comparative exposure data in Figures 7 to 10, shows that installations of alloy 63S should parallel the good service record of predecessor alloys (53S and 43S) dating back to 1926.

The high strength heat treatable alloys (Table I), such as 14S, 17S, 24S, which contain large amounts of copper and minor additions of other elements, and alloy 75S, which contains large amounts of zinc, magnesium and copper, do not have as high a resistance to corrosion as the preceding groups of alloys. It is generally recommended, therefore, that adequate protection be provided these alloys when exposed to the weather. The alclad forms of these alloys possess a very high inherent resistance to corrosion and may be used without benefit of protective coatings.

#### Alclad Products

Alclad products are outstanding in their ability to resist corrosion and maintain the structural integrity of the product. A clear understanding of the characteristics of their performance is desirable.

Alclad products have been discussed in detail by Dix.<sup>6</sup> They are composite in type, consisting of an aluminum alloy core to which is bonded metallurgically protective coatings<sup>7,8</sup> of pure aluminum or of another aluminum alloy (Figure 16). The core alloy is chosen to develop the desired mechanical properties. The cladding alloy is of such a composition as to provide a surface that has a high inherent resistance to corrosion and is also sufficiently anodic to the core alloy to afford substantial electrochemical protection to it in most corrosive environments. Consequently, any spot of attack will penetrate only as far as the core alloy (or diffusion zone) where further progress is stopped by cathodic protection. Corrosion then proceeds laterally along the surface, being confined to the cladding. The life of the cladding is a function of its thickness and the severity of the environment. Alclad products, therefore, provide maximum resistance to perforation by limiting

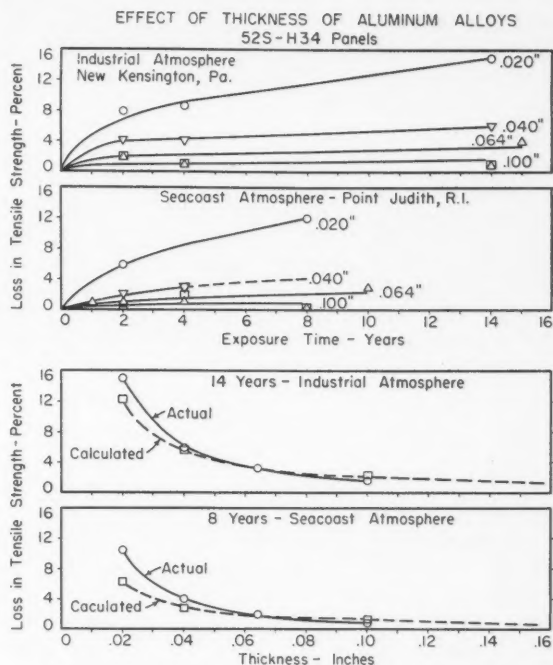


Figure 18—The data obtained at 8 years and 14 years (top curves) were plotted (bottom curves) to show the correlation between percent loss in strength and thickness of the alloy. Included for comparison are curves showing calculated percent losses in strength based on factual data obtained from 0.064-inch thick specimens.

corrosion to a relatively thin surface layer. Furthermore, the core alloy exposed at cut edges, scratches, or abrasions is afforded adequate electrochemical protection by adjacent alclad coating.

The excellent resistance to weathering of alclad products is illustrated by the data (Figure 16) obtained on Alclad 3S, Alclad 17S-T3 and Alclad 24S-T3 specimens which have been exposed for periods of from 10 to 20 years. With regard to the tensile data included in Figure 16, the somewhat higher losses in strength for the Alclad 3S in comparison with those for the Alclad 24S-T3 and Alclad 17S-T3 do not necessarily indicate that the former had corroded to a greater extent. The pure aluminum cladding applied to the high strength alloys, 17S-T3 and 24S-T3, contributes very little to the strength of these products; thus, corrosion of the cladding causes negligible changes in strength. In the case of alloys such as Alclad 3S and Alclad 4S, the coating alloy of 72S(9) does contribute to the strength of the product, and corrosion of the cladding is reflected in proportionally higher losses in strength.

It is apparent that high resistance to corrosion can be secured from clad products of the high strength structural alloys. This has been demonstrated by Alclad 75S-T6 sheet in aircraft construction and Alclad 14S-T6 plate in bridge structures. Some idea of the value of alclad protection, especially for the high strength aluminum alloys, is apparent from the results of the ASTM tests<sup>2</sup> on 17S-T3 and Alclad 17S-T3. After 10 years' exposure at La Jolla, California, 0.035-inch thick tension specimens (pre-machined) of 17S-T3 lost 50 percent in tensile

strength, whereas similar tension specimens of Al-clad 17S-T3 revealed a loss of only 2 percent.

Although non-clad aluminum alloys, such as 3S and 4S, have exhibited a high resistance to atmospheric weathering, there are situations where it is advantageous to use these alloys in their alclad forms (Figure 17), particularly where the metal is relatively thin and where maximum resistance to perforation is required. For example, alclad sheet is especially valuable for applications involving gutters, down spouts, flashing, and valleys, etc., where the hazards of corrosion and perforation are increased by continual contact with water absorptive materials, such as wood, leaves and soil.

### Effect of Thickness

Some measure of the effect of atmospheric weathering on different thicknesses of aluminum alloys is illustrated by the data in Figure 18. These tests made on panels of aluminum alloy 52S-H34 show that for all thicknesses studied (0.020-inch to 0.100-inch) the rate of corrosion decreased with time, both in industrial and seacoast atmospheres. The data have also been plotted to provide a means of interpolating the relative performance expected from the same alloy in other thicknesses.

In those many cases where the effect of atmospheric weathering on the tensile strength of a given alloy are available on one thickness only, it would be advantageous to be able to estimate the effects on different thicknesses. The percent loss in tensile strength for various thicknesses can be calculated (see Footnote) from actual data obtained for any one thickness, assuming that the magnitude and pattern of corrosion is about the same for all thicknesses of the alloy. Calculated percent losses in tensile strength for the various thicknesses of 52S-H34 are included in Figure 18.

The calculations were based on data secured from 0.064-inch thick material, since most of the tests herein were made on material of this thickness. These calculated values show reasonable agreement with actual data although they tend to overestimate

1. When tension specimens are machined from panels after exposure, percent losses in tensile strength are inversely proportional to the thicknesses:

$$\frac{L_0}{L_1} = \frac{t_1}{t_0}$$

Where  $L_0$  = actual percent loss in tensile strength for specimens of original thickness,  $t_0$

$L_1$  = percent loss in tensile strength to be calculated for specimens of original thickness,  $t_1$

2. When tension specimens are machined before exposure, edge attack must be considered, and the following formulas are applicable:

$$1. L_0 = \frac{2d(t_0 + W - 2d)}{Wt_0}$$

$$2. \frac{L_0}{L_1} = \frac{t_1}{t_0} \cdot \frac{(t_0 + W - 2d)}{(t_1 + W - 2d)}$$

Where:  $W$  = standard width of tension specimens (0.500 in.)

$d$  = a geometrical corrosion factor (having the dimensions of depth of attack) responsible for the percent loss in tensile strength,  $L_0$ .

the effect of the corrosion on the alloy in sections thicker than 0.064-inch and underestimate the effect of the thinner materials.

This method was used to provide a means for comparing the corrosivity of the Alcoa exposure stations at New Kensington and Point Judith with nine different ASTM exposure stations, even though the materials had been exposed in different thicknesses (Figure 4).

### Cast Aluminum Alloys

Substantial atmospheric weathering data obtained over a 20-year period on several aluminum alloy sand castings and over a 19-year period on various aluminum alloy die castings are summarized in Figures 19 to 23. In general, long time atmospheric weathering caused only small losses in tensile strength of the 1/2-inch diameter sand-cast test specimens and the 1/4-inch diameter die-cast specimens. Thus, the situation for casting alloys, especially those without substantial amounts of copper, is analogous to that for wrought alloys in that for many applications the resistance to corrosion of various casting alloys is sufficiently similar that final choice is based on other characteristics, such as castability, soundness, strength and economy. Only in the more severe environments, such as the seacoast atmosphere at Point Judith, do conspicuous differences in resistance to corrosion inherent to the various alloys become apparent. For example, aluminum casting alloys containing substantial amounts of copper are noticeably less resistant to corrosion in the more severe exposures than alloys not alloyed with copper.

Since the long time atmospheric weathering data have been obtained on alloys of varied composition, it would seem desirable to discuss them in the light of the class of alloy they represent.

### Aluminum-Copper Alloys

Aluminum casting alloys containing substantial amounts of copper do not maintain as good a surface appearance as the other alloys and are not generally used in architectural applications where maximum resistance to surface attack is desired.

The data on Alloy 12 (8% Cu) are of interest because it is one of the oldest aluminum casting alloys and its performance is well known to the casting industry. This alloy provides a good basis of reference, since the alloys subsequently developed for outdoor exposures have a resistance to corrosion superior to that of alloy 12 (Figures 19, 20).

Alloy 112 is a modification of alloy 12 with improved machinability and castability and now is preferred over the older alloy. The resistance to corrosion of the two alloys has been found to be practically identical. Alloy 195, a heat treatable alloy containing less copper (4.5%) generally exhibited a better resistance to corrosion both in the naturally aged temper (—T4) and particularly in the artificially aged temper (—T6), as indicated by Figures 19, 20.

### Aluminum-Silicon Alloys

The aluminum-silicon alloys are noted for their excellent casting characteristics combined with good

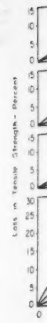


Figure 18 shows the relationship between tensile strength and thickness for aluminum alloy 52S-H34.

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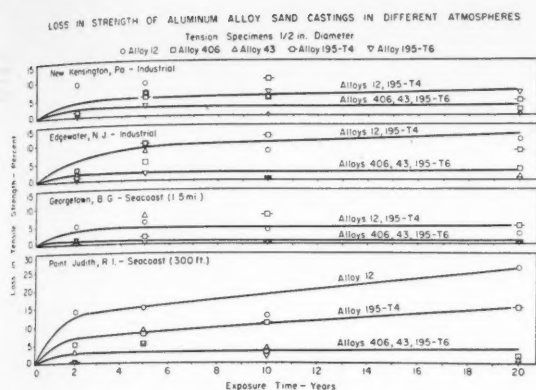


Figure 19—These curves and subsequent ones (Figures 20 through 23) show that the corrosion of aluminum alloy castings also display "self-stopping" characteristics. Note that exposures for as long as 20 years generally caused only small losses in strength of these 1/2-inch cast test bars.

resistance to atmospheric weathering. This class, represented by Alloy 43 (5% Si) and Alloy 13 (12% Si), has displayed a high resistance to weathering (Figures 19 to 23) both as sand castings and as die castings. Consequently, the aluminum-silicon alloys have been popular for many architectural applications. Because of a characteristic gray color developed by these alloys when anodically coated, they are often used advantageously to provide contrasting effects with other building materials in architectural applications.

#### Aluminum-Copper-Silicon Alloys

Variations in silicon and copper in this family of alloys are intended to yield good castability and high strength. Because of the copper additions, the resistance to corrosion of these alloys is not as good as that of the aluminum-silicon alloys (Figures 19 through 23) and is closer to that of the aluminum-copper alloys. Even though this class, including alloys 85, 380, 384, may show more surface attack than the aluminum-silicon alloys, it is gratifying to note (Figures 21, 22) that test specimens 1/4-inch in diameter revealed shallow attack and only small to moderate losses in tensile strength after about 16 years' exposure to relatively severe atmospheres.

#### Aluminum-Magnesium Alloys

Aluminum-magnesium type casting alloys, such as 214, B214, 218 and 220 provide high strength and excellent resistance to corrosion. The casting characteristics of these alloys, however, are not as good as those of the preceding alloys. The aluminum-magnesium alloys show to best advantage in their ability to resist surface attack and maintain a pleasing appearance, especially to severe marine environments, as typified by the salt spray exposure (Figure 23).

#### Aluminum-Silicon-Magnesium Alloys

The aluminum-silicon casting alloys do not have the strength required for some applications. The addition of small amounts of magnesium makes these alloys respond to heat treatment and artificial aging, which

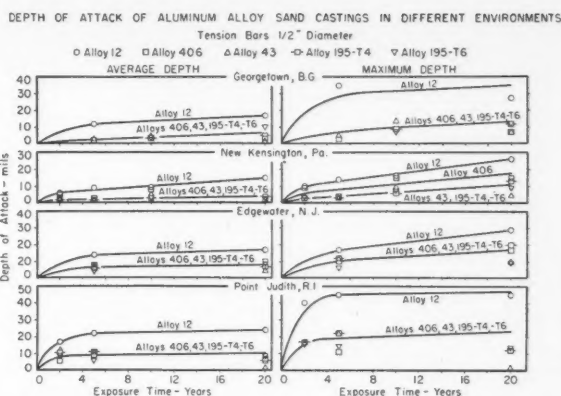


Figure 20—The depth of attack curves for the aluminum casting alloys are analogous to those for the aluminum wrought alloys, although the attack is somewhat deeper for the casting alloys. The depth of attack and losses in strength (Figure 19) were consistently greater for alloy 12 (8% copper) than for the other aluminum alloys.

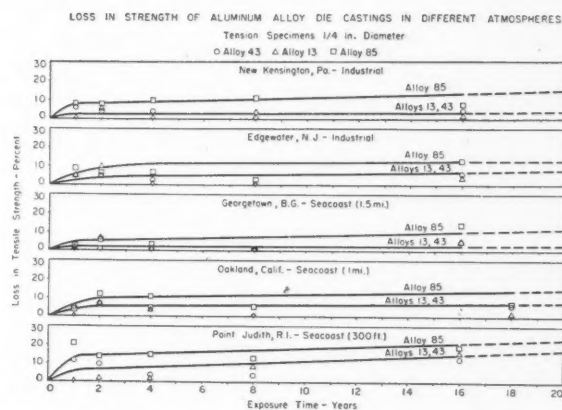


Figure 21—Specimens for this test were die cast in a gooseneck machine. These long time exposures usually caused only small losses in strength of the 1/4-inch diameter bars; and alloys 13 and 43 were consistently superior to alloy 85.

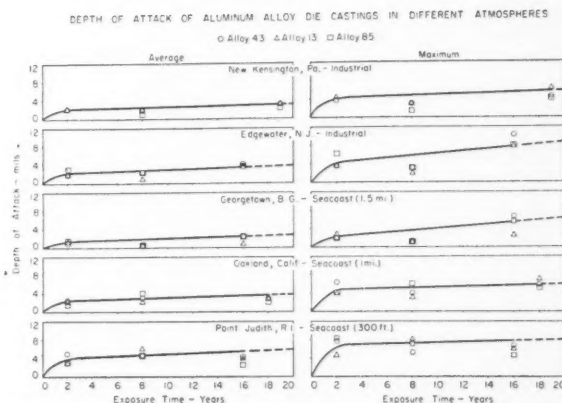


Figure 22—Depth of attack for the aluminum alloy die castings was shallower than that for sand castings (Figure 20). Differences in depth of attack of these die casting alloys were negligible. Thus, the higher losses in strength for alloy 85 (Figure 21) indicate that surface attack was more widespread on this alloy than on alloys 43 and 13.

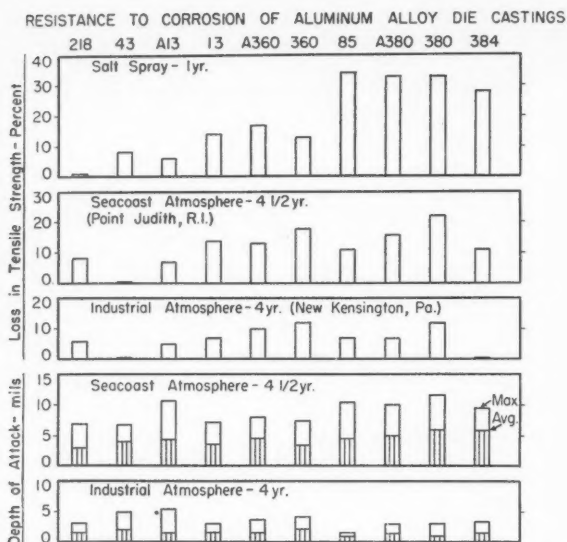


Figure 23—The  $\frac{1}{4}$ -inch diameter tension bars for this investigation were die-cast in cold-chamber machines, and include a wide variety of aluminum alloys (Table II). In outdoor exposures the main difference has been one of surface appearance, with the magnesium rich alloy (218) providing the best appearance, followed by the silicon bearing alloys, then the copper bearing alloys. The salt spray data were included to indicate the relative performance of these alloys under unusually severe conditions.

imparts considerable increase in strength. This is achieved without appreciable change in resistance to corrosion, as is evident from comparing the good performance of alloy 360 (9.5% Si, 0.5% Mg) with the aluminum-silicon alloys 43 and 13 (Figure 23). These data were secured on die castings, but sand casting and permanent mold casting alloy 356 (7% Si, 0.3% Mg) is performing in a similar manner, as judged by tests of shorter duration. This class of

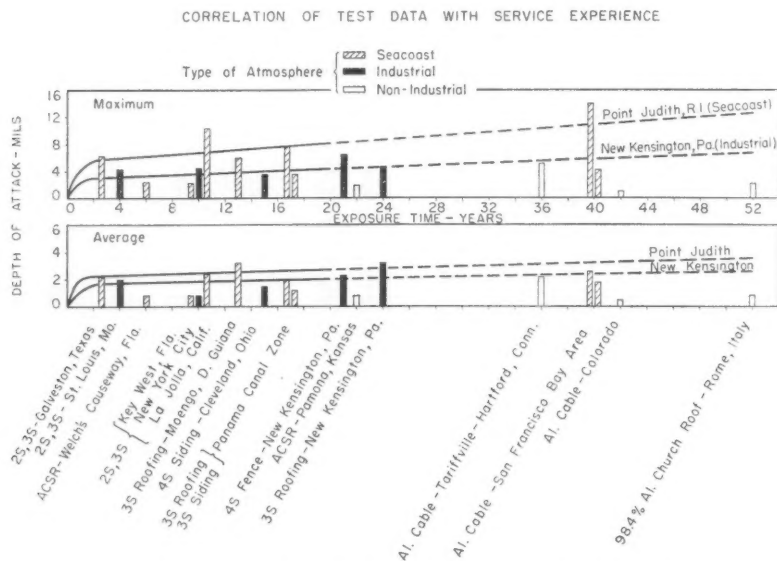


Figure 24—Curves for the atmospheres listed were based on data obtained on aluminum alloys 2S, 3S and 4S, with the curves extrapolated to 52 years. Data obtained on test specimens at other exposure stations and on related aluminum alloys from a variety of service conditions are superimposed (bars) on these curves. This supplementary information adds considerable significance to the data provided by these basic exposure stations.

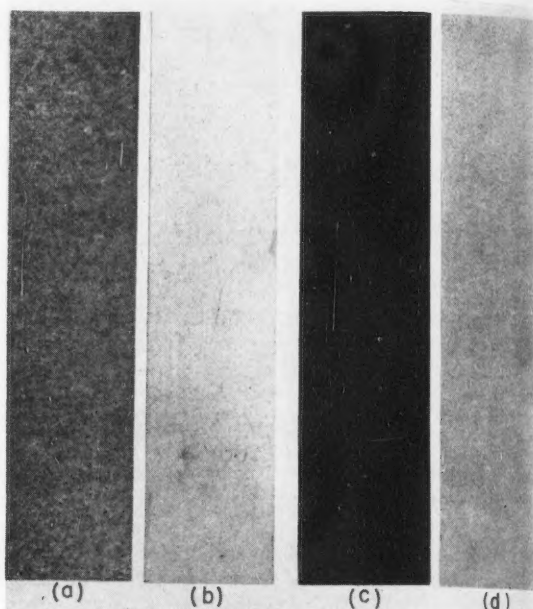


Figure 25—Representative coupons (1½-inch by 6½-inch) of 4S sheet illustrating the gray patina developed by aluminum alloys when exposed for many years to severe seacoast conditions (a)—8 years at Point Judith—and the darkened appearance of the metal when exposed in industrial atmosphere containing considerable carbonaceous products from bituminous fuel (c)—20 years at New Kensington. Surfaces untouched for many years in severe environments are not cleaned quickly with mild cleaners, but are more readily cleaned with certain acid type cleaners, such as proprietary phosphoric acid type solutions suitable for cleaning aluminum prior to painting. The coupons (b) and (d) at the right in each set were cleaned (after exposure) simply by swabbing the surface with one such cleaner. Such cleaners should be confined to the work and rinsed with water, with adjacent architecture protected since the cleaners may also etch or streak masonry, etc.

alloy (356 and 360) combines excellent castability, high strength and good resistance to corrosion.

#### Aluminum-Manganese Alloys

Aluminum-manganese casting alloys, such as alloy 406 (2% Mn) are highly resistant to corrosion (Figures 19, 20) but are being superseded by alloys, such as 43 and B214, which have better casting characteristics and comparable resistance to corrosion.

#### Service Experience

There have been many incidental opportunities to examine samples of aluminum alloys from actual installations in service for periods up to 52 years in widely scattered localities. These installations involved roofing and siding of alloys 2S, 3S, and 4S; fencing of alloy 4S and electrical conductors of E. C. grade aluminum either as all aluminum cable or as aluminum cable

steel reinforced (Alcoa ACSR). The effect of the diverse exposures was evaluated by measurement of depth of attack. Data from a number of service installations are presented in Figure 24. It is apparent that the attack was shallow and generally less than that for related aluminum alloys when exposed at Alcoa's basic weathering stations at New Kensington and Point Judith. The data from these relatively severe exposure stations can be used, therefore, to estimate the performance expected from aluminum alloys when subjected to the weather at most localities.

### Other Factors

In structures involving a variety of building materials, metallic and non-metallic, there are factors other than the weather per se which are important. A number of these have been treated categorically by Mears and Brown<sup>10</sup> and by Dix and Brown.<sup>8</sup> However, some remarks pertinent to building and construction applications are justified.

### Surface Appearance

For architectural applications, in particular, the effect of weathering on the surface appearance of a metal is important. In the case of aluminum alloys, the products of weathering are light in color and usually adhere tenaciously to the metal. Thus, weathering of aluminum alloys does not result in staining of adjacent architecture. Because of the light color of their corrosion products, aluminum alloys tend to acquire a light gray patina. This transformation proceeds very slowly in clean atmospheres away from the seacoast, so that surfaces may retain some metallic sheen even after many years. Weathering proceeds appreciably faster at seacoast locations, so that over a period of several years the surface acquires a dull gray appearance, which does not change much with time (Figure 25). In industrialized or urban areas, especially those utilizing bituminous coal as fuel, the accumulation of carbonaceous materials gradually darkens aluminum alloy products (Figure 25) as well as other building materials. Vertical surfaces discolor at a much slower rate than inclined surfaces. Thus, aluminum alloy windows and doors usually remain light in color, particularly if washed occasionally, whereas roofing darkens. Sheltered surfaces of aluminum alloys (and other metals) generally develop a thicker and rougher oxide coating than do boldly exposed surfaces, which are frequently washed by rain.

### Maintenance

Aluminum alloy parts respond favorably to periodic maintenance of a simplified nature. Bare surfaces usually can be kept clean simply by washing with a mild soap or detergent. The use of fine steel wool with liquid wax cleans and brightens the metal and leaves a protective film which helps to preserve a pleasing appearance. Installations that have been ignored for extended periods can also be cleaned, but they will often require stronger measures, such as the use of a mild etchant, to facilitate the removal of adherent grime and products of weathering (Figure 25).

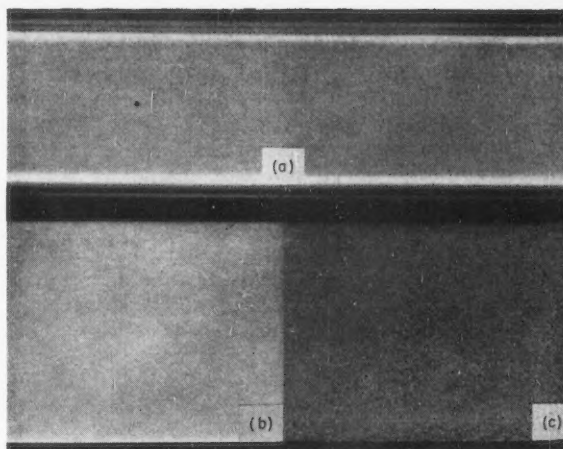


Figure 26—Anodically coated (Alumilite Finish No. 204A1) sections of alloy 535 after 15 years' exposure to the industrial atmosphere at New Kensington, Pennsylvania. Section (a) was cleaned monthly during the first year, using fine steel wool and liquid wax, and remained in excellent condition. When not maintained during the next eight years, the surface gradually darkened and the coating developed some minute breakdowns (not discernible at several feet); however, the original smooth, satin finish was restored by cleaning with fine steel wool and an abrasive wax cleaner and monthly cleaning for the last six years with steel wool and liquid wax has preserved this finish. The history of the bottom sample paralleled that of (a) except that the sample was not maintained between the 9 and 15 year periods. Thus, (c) shows dirt accumulation over six year period and (b) shows the good surface finish easily restored by cleaning with fine steel wool and abrasive wax cleaner.

### Anodic Coatings

For applications where an attractive surface and a minimum of maintenance is of considerable importance, much can be gained from the use of anodically coated aluminum alloys. Anodic coatings formed in a sulfuric acid electrolyte (Alumilite coatings) can be varied in thickness to meet specific needs and the oxide coatings thus produced are much thicker, more abrasion resistant and more protective than the natural oxide film.<sup>11</sup> These anodic coatings enhance the surface appearance of aluminum alloys and provide excellent resistance to weathering and discoloration. If the coatings are of the desired thickness for the application and are cleaned regularly, the original surface finish can be preserved. If neglected, the surface will slowly become soiled and may show some coating breakdowns. However, in most cases the integrity of the anodic coating is not affected, so that the coated part is more easily cleaned than is bare metal (Figure 26).

### Non-Metallics

Contact of aluminum alloys with non-metallic building materials does not involve any corrosion problems under the dry conditions that prevail within most buildings. Under continually wet or damp conditions, however, corrosion hazards may be associated with water absorptive materials, such as wood, insulation and masonry. Corrosion from such causes usually can be mitigated by one or a combination of the following expedients:

- a) back painting the aluminum alloy with a good quality paint (free from lead pigmentation);



- b) painting the non-metallic material;
- c) interposing a uniform layer of a mastic compound between the aluminum alloy and the wood or masonry, etc.

During construction, exterior surfaces of aluminum alloys (and other metals) require temporary protection, especially against the diverse materials that settle over or are splashed onto them. Commonly encountered are alkaline materials, such as plaster, mortar and concrete, which can stain or even pit unprotected metals. Alkali resistant clear lacquer coatings (such as those using acrylic resins), about 0.5 to 1.0 mil thick, provide good resistance to the action of these materials and greatly facilitates subsequent cleaning of the surfaces. This protective measure is commonly used for both bare and anodically coated aluminum alloy installations.

#### *Dissimilar Metals*

Aluminum alloys are anodic to most other metals of construction, such as alloys of iron, copper, nickel, lead and tin and may suffer galvanic attack when coupled to them. It is best, therefore, to avoid the use of dissimilar metals where practicable. Atmospheric exposures, however, are far less conducive to galvanic attack than are exposures by immersion, such as in sea water. The hazards of galvanic attack can be substantially minimized through selection of the most compatible metals suitable for the job and by employing protective coatings if necessary.

Because zinc and cadmium do not stimulate galvanic attack of aluminum alloys, zinc plated (galvanized) or cadmium plated steel or other metals are suitable for use with aluminum alloys for such applications where the coatings have adequate life. Although stainless steels and chromium (also titanium) are more cathodic than mild steel, copper and nickel, they cause much less galvanic attack on aluminum alloys. Aluminum alloys and stainless steels (especially the 300 series) have successfully combined their respective advantages in many atmospheric applications. The desirable characteristics of chromium can be used to advantage as platings on alloys of iron, copper and nickel, thereby greatly reducing or even eliminating the hazards of galvanic attack, which may result when these metals are used with aluminum under adverse conditions. Best results are achieved when the chromium coating is applied over a plate of nickel.

In atmospheric exposures, galvanic attack is apt to be most severe in crevices where moisture can be trapped between dissimilar metals and remain for long periods. Such attack can be stifled by providing weather-tight joints, by painting the faying surfaces and most effectively by sealing the joints with a mastic compound.

Drainage from some dissimilar metals, notably alloys of copper and nickel, onto aluminum alloys can have deleterious effects. This results from "heavy metals," such as copper and nickel being washed from the cathodic metals and deposited on the aluminum surface where they excite electrochemical attack of the aluminum. Wash from dissimilar metal parts small in area may not supply heavy metals in sufficient quantity to be harmful, but the greater quantity draining from large surface areas (roofing, copings) can contaminate underlying

surfaces of aluminum alloys sufficiently to cause severe corrosion. Wash from ferrous metals generally has not been adverse to aluminum alloys. The foregoing situation should be avoided wherever feasible; if encountered, the best remedial measure is to maintain paint protection over one or both metal components depending on circumstances.

#### **Conclusions**

1. Outdoor exposure of thousands of specimens for long periods to a variety of conditions, including severe industrial and sea-coast atmospheres, shows that aluminum alloy products, both wrought and cast, have a high resistance to atmospheric weathering.
2. This is attributable to the "self-stopping" nature of the attack of aluminum alloys; that is, the formation of protective films which causes the rate of weathering to decrease markedly with time.
3. The data indicate that after an initial exposure period of about one or two years, the maximum rate of penetration of corrosion is expected to be appreciably less than 0.2 mil per year for the more adverse conditions, such as severe sea-coast atmospheres and less than 0.1 mil per year for atmospheric weathering conditions normally encountered.
4. Although some differences in resistance to weathering were noted among the aluminum alloys, the differences often were of little practical significance so that final choice of alloy would be based on other important requirements, such as strength, formability, weldability, appearance and cost.
5. Alclad products are characterized by a high resistance to weathering and also by a unique resistance to perforation. The performance of alclad alloys makes them especially valuable for applications involving relatively thin sheet products for use under adverse conditions.

#### **Acknowledgments**

The work reported herein is the result of the concerted efforts of many individuals in several divisions of the Aluminum Research Laboratories. Particular credit is due E. H. Dix, Jr., who foresightedly planned many of the investigations which form the backbone of this paper; to R. H. Brown for his helpful suggestions and contributions to this paper and to F. M. Howell, E. C. Hartmann, and F. Keller under whose supervision the numerous tensile tests, engineering assistance and metallographic examinations were provided. H. C. Slaughter was of considerable help in expediting the various tests made on the many specimens evaluated at the 20-year period. The graphs were drawn by K. H. Maier.

#### **References**

1. R. B. Mears and R. H. Brown. Resistance of Aluminum-Base Alloys to Marine Exposures. *The Society of Naval Architects and Marine Engineers, Transactions*, 52, 91-113 (1944).
2. E. H. Dix, Jr. and R. B. Mears. The Resistance of Aluminum-Base Alloys to Atmospheric Weathering. Symposium on Atmospheric Exposure Tests on Non-Ferrous Metals, American Society for Testing Materials, 1946, pp. 131-176.
3. E. H. Dix, Jr. and R. H. Brown. Resistance of Aluminum Alloys to Corrosion. *Metals Handbook*, American Society for Metals, 1948, pp. 791-797.
4. W. W. Binger, R. H. Wagner, R. H. Brown. Resistance of Aluminum Alloys to Chemically Contaminated Atmospheres, National Association of Corrosion Engineers' Ninth Annual Conference, March 16-20, 1953.
5. Standard Methods of Tension Testing of Metallic Materials (E8-52T). 1952 Book of ASTM Standards, Part II, p. 1208.
6. Edgar H. Dix, Jr. Aluminum-Clad Products. *Engineering Laminates*, 1949.
7. Edgar H. Dix, Jr. U. S. Patent 1,865,089 Corrosion-Resistant Aluminum Alloy Articles and Methods of Making the Same. June 28, 1932—filed Jan. 22, 1927.
8. Edgar H. Dix, Jr. Alclad—A New Corrosion-Resistant Aluminum Product. *Natl. Advisory Comm. Tech. Note* 259 (Aug. 1947).
9. Robert H. Brown, U. S. Patent 1,997,165 Duplex Metal Article (April 9, 1935—filed Oct. 20, 1933).
10. R. B. Mears and R. H. Brown. Designing to Prevent Corrosion. *Corrosion*, 3, No. 3, 97-118 (1947) March.
11. F. Keller and Junius D. Edwards. Performance and Structure of Anodic Coatings on Aluminum. *Iron Age*, 56-75-78 (1945) Nov. 22.

## A SURVEY

# Corrosion Resistance of Beryllium Copper\*

By JOHN T. RICHARDS

**T**HE ABILITY of beryllium copper to combine good corrosion resistance with other desirable properties is frequently the reason for its selection by designers. Like other copper-base alloys, it is non-magnetic and offers good electrical and thermal conductivity. Unlike other copper materials, however, it can be heat treated to a high level of strength and hardness.

Although the term "beryllium copper" refers to a family of alloys, this survey is mainly concerned with the standard material containing nominally 1.9 percent beryllium. Unless otherwise stated, all data refer to this alloy. Typical properties and compositions for wrought and cast forms will be found in Tables I and II. More complete property and processing information appears elsewhere.<sup>1</sup>

The useful properties of beryllium copper result from a two-step thermal treatment. The first or solution-annealing step (1475-1500 F followed by a water quench) softens the material. This operation is generally handled by the mill prior to shipment. The second step or aging treatment (550-750 F followed by cooling at any convenient rate) hardens the material to the desired level. By altering the aging time and temperature, it is possible to select various combinations of strength, hardness, conductivity, ductility and impact resistance. In view of the hardness attained through heat treatment, it is customary to form or machine parts prior to age hardening.

In a manner similar to other high-copper products, beryllium copper provides good resistance to fresh or salt water, marine and industrial atmospheres, many alkaline solutions and some acids. The statement that the corrosion resistance of beryllium copper is equivalent to that of copper<sup>2,3</sup> may be too general for many specific cases. Accordingly, it is the purpose of this survey to present available data to permit a better evaluation of the corrosion resistance of beryllium copper.

### Aqueous Media

#### Fresh and Salt Water

Beryllium copper offers good resistance to natural fresh and sea water, providing somewhat better resistance than copper. Table III indicates the effects of temper, age hardening, test temperature and beryllium content upon corrosion by normal and artificial sea water. Corrosion rates are expressed in milligrams per square decimeter per day (mdd) and inches penetration per year (ipy).

As indicated in the table, corrosion decreases with increasing beryllium content but increases slightly with moderate temperatures. Although temper or

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### Abstract

Available data are presented on the resistance offered by beryllium copper to corrosion by various media including fresh and salt water, acids, alkalis and liquid metals. Attack by various atmospheres is considered and the resulting corrosion products are described. The possible role of internal oxidation or sub-scale formation is also discussed. Other forms covered include galvanic corrosion, cavitation erosion, stress-corrosion and corrosion fatigue. The effect of corrosion on the processing of beryllium copper products is noted, while typical applications where corrosion may present a problem are briefly reviewed.

condition do not appear to affect corrosion rates, the addition of copper chloride to artificial sea water has a marked effect. There is no appreciable difference between the effect of sea water and artificial sodium chloride solutions.

Although it has not been possible to obtain his

TABLE I—Typical Properties of Wrought Beryllium Copper

Nominal Composition	Beryllium .. 1.9% Cobalt .. 0.2% Copper .. balance			
	Condition and Heat treatment		Heat treated 2-3 hours at 600 F	
Temper	Solution Annealed (A)	Half Hard (½ H)	Solution Annealed (AT)	Half Hard (½ HT)
<b>Physical Properties:</b>				
Density, lb per cu in.....	0.299	0.299	0.301	0.301
Melting range, F.....	1600-1800	1600-1800	1600-1800	1600-1800
Electrical conductivity, Percent IACS, 68 F.....	17-19	15-17	22-30	22-30
Thermal conductivity, btu/sq ft/in/hr °F, 68 F...	470-600	470-600	750-890	750-890
<b>Average coefficient of linear expansion:</b>				
Per deg. F, —100 to +70 F	0.0000090	0.0000090	0.0000090	0.0000090
+70 to +572 F	0.0000094	0.0000094	0.0000094	0.0000094
<b>Hardness:</b>				
Rockwell, B or C scale.....	B45-78	B88-96	C36-41	C39-44
Superficial.....	30T46-67	30T74-79	30N56-61	30N59-65
<b>Tensile Properties:</b>				
Ultimate tensile strength, psi	60-78,000	85,100,000	165-190,000	160-220,000
Elongation in 2 in., percent..	35-60	5-20	4-10	2-6
Proportional limit (0.002% offset), psi.....	15-20,000	50-70,000	100-135,000	120-160,000
Yield strength (0.2% offset), psi.....	28-36,000	75,110,000	140-175,000	160-220,000
Elastic modulus, psi.....	17,000,000	16,500,000	19,000,000	18,500,000
Izod impact strength, in.-lb....	100-110	32-40	12-15	10-14
<b>Fatigue strength at 100,000,000 cycles:</b>				
Strip, reversed bending, psi..	30-35,000	32-38,000	35-40,000	38-48,000
Rod, rotating beam, psi.....	.....	.....	45-60,000	45-60,000

\* A paper presented at the Ninth Annual Conference, National Association of Corrosion Engineers, Chicago, Ill., March 16-20, 1953.

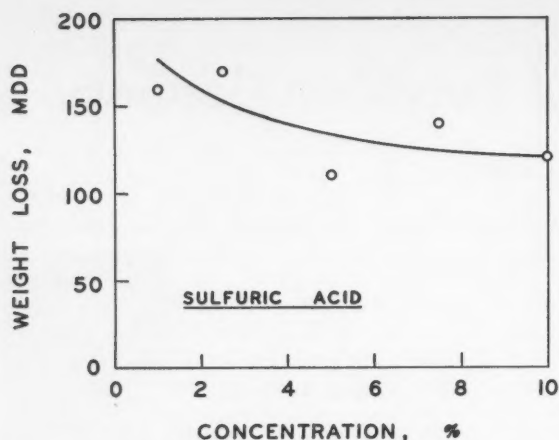


Figure 1—Weight loss of a 2.05 percent beryllium copper alloy (as cast) continuously immersed for 24 hours at 68 F in various concentrations of sulfuric acid. Terem.<sup>(6)</sup>

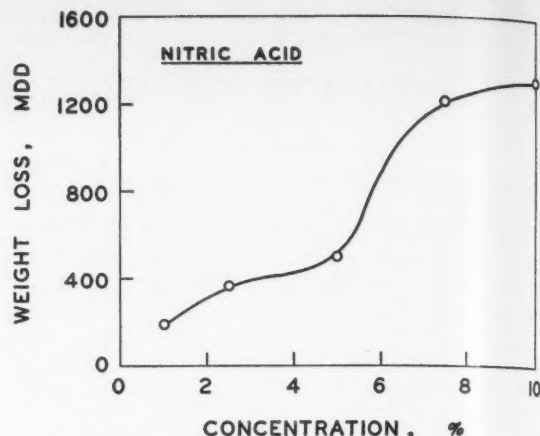


Figure 2—Weight loss of a 2.05 percent beryllium copper alloy (as cast) continuously immersed for 24 hours at 68 F in various concentrations of nitric acid. Terem.<sup>(6)</sup>

TABLE II—Typical Properties of Cast Beryllium Copper

Nominal Composition	Beryllium .. 2.0% Cobalt .. 0.4% Copper .. balance			
	Heat Treatable		Heat Treated 2-3 hours at 650 F	
	Condition	Cast	Cast and Solution Annealed	Cast and Solution Annealed
<b>Physical Properties:</b>				
Density, lb per cu in.	0.290	0.290	0.292	0.292
Melting range, F.	1585-1780	1585-1780	1585-1780	1585-1780
Electrical conductivity, Percent IACS, 68 F.	17-22	14-18	19-24	20-25
Thermal conductivity, Btu/sq ft/in./hr./°F, 68 F.				650-800
<b>Average coefficient of linear expansion:</b>				
Per deg F, 68 to 392 F.	0.000009	0.000009	0.000009	0.000009
<b>Hardness:</b>				
Rockwell, B or C scale.	B75-85	B65-75	B90-100	C-38-45
<b>Tensile properties:</b>				
Ultimate tensile strength, psi	70-85,000	60-70,000	85-110,000	150-175,000
Elongation in 2 in., percent	15-30	30-45	10-25	1-4
Proportional limit (0.002% offset), psi	20-30,000	8-15,000	25-40,000	105-125,000
Yield strength (0.2% offset), psi	40-50,000	25-40,000	45-60,000	115-155,000
Elastic modulus, psi	17,500,000	17,000,000	18,500,000	18,500,000
Izod impact strength, in.-lb.	65-80	90-110	50-60	5-12
<b>Fatigue strength at 100,000,000 cycles:</b>				
Rotating beam, psi				20-30,000

report, Bojkov<sup>4</sup> has determined certain corrosion rates for various beryllium copper alloys. Some specimens were subjected to continuous and intermittent immersion in artificial sea water for 1380 hours. Others were suspended over boiling sea water. Best resistance was offered by an alloy containing 1.95% beryllium, 4.35% aluminum, balance copper.

#### Acids

In acids, beryllium copper compares favorably with pure copper. While good resistance is offered to non-oxidizing acids, oxidizing acids (including nitric and chromic) as well as those containing certain metallic salts may prove extremely corrosive. In general, beryllium copper is not rapidly corroded by dilute sulfuric, cold concentrated sulfuric, cold dilute hydrochloric and many organic acids. However, corrosion rates may increase, often to a high degree with temperature, velocity, aeration and concentration.

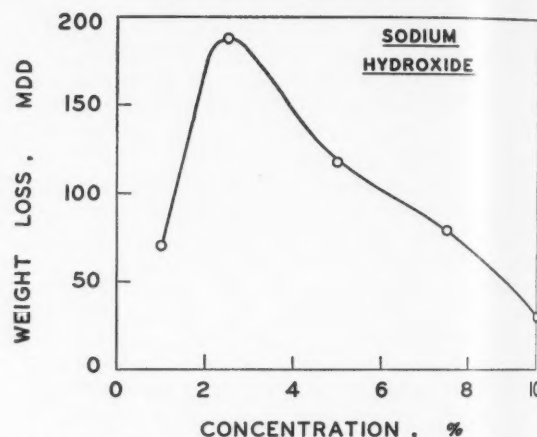


Figure 3—Weight loss of a 2.05 percent beryllium copper alloy (as cast) continuously immersed for 24 hours at 68 F in various concentrations of sodium hydroxide. Terem.<sup>(6)</sup>

As indicated in Tables IV and V, corrosion rates in sulfuric acid vary widely and are apparently dependent upon beryllium content, concentration (see Figure 1) and temperature. Although heat treatment has no marked effect, the addition of an oxidizing agent such as potassium dichromate increases corrosion rates to a high degree. Variation among the results of individual investigators is rather wide and is probably due to differences in method. Terem<sup>3</sup> alone has described test procedures in detail.

Generally, hydrochloric acid attacks beryllium copper at the same rate as sulfuric acid (see Tables VI and VII). From the results presented, beryllium copper is equal to aluminum bronze but superior to either copper or tin bronze in resisting hydrochloric acid.

The influence of various concentrations of nitric acid on alloys of different beryllium contents are given in Table VIII and Figure 2. Similar data for acetic acid are presented in Table IX. Although corrosion rates in nitric acid are excessive for safe handling, beryllium copper provides sufficient resistance to acetic acid to make it practical for many applications.



As part of an extensive corrosion testing program conducted by the Tennessee Valley Authority, Yates<sup>6</sup> has reported considerable data on the corrosion of many materials exposed to phosphoric acid under laboratory and plant conditions. Part of these results are reproduced in Table X. Disk specimens were mounted on spools and exposed from 15 to 30 days in plant and pilot plant sumps, tanks, pipelines, etc. The data listed in the last column of the table were obtained in plant vapor ducts that contained phosphoric acid as mist and some fluorine, probably present as hydrogen fluoride. Although oxygen and water vapor were also present, the principal constituent of the gas carrying the mist was nitrogen. On account of the nature of these tests, close control was not exercisable over concentration, temperature or aeration.

#### Alkalies

Good results have been obtained with beryllium copper in many cold concentrated and hot or cold dilute alkalies. Sodium and potassium hydroxide solu-

tions can be handled at room temperature, but ammonium hydroxide rapidly attacks beryllium copper. Data for sodium and ammonium hydroxide will be found in Tables XI and XII. The effect of sodium hydroxide concentration is illustrated in Figure 3.

#### Organic Media

Beryllium copper provides excellent resistance to such organic chemicals as hydrocarbons, alcohols, ketones, aldehydes and esters. Water-free organic compounds are generally noncorrosive at ordinary temperatures but increases in temperature and moisture may accelerate corrosion rates. Good resistance is also offered to fluorinated hydrocarbons.

#### Atmospheric Attack

Like other copper-base alloys, beryllium copper will stain and darken when exposed to humid or sulfur-bearing atmospheres. A black surface is produced in sulfide atmospheres, while a green film results from salt deposited in marine or salt-spray exposures. The tarnish formed has no apparent influence upon mechanical properties.

Salt spray tests indicate that beryllium copper becomes covered with a green film, but that even after six weeks the green tarnish is still superficial.<sup>7,8,9</sup> The influence of beryllium content upon resistance to salt-spray corrosion is indicated in Figure 4.<sup>10</sup>

Tests also have been conducted under conditions of cyclic humidity. The daily cycle includes 8 hours in a warm dry atmosphere averaging 130 F and 65 percent humidity. This is followed by 16 hours in dampness (100 percent humidity with condensate) obtained by cooling to atmospheric temperature. Under these conditions, beryllium copper exhibited only slight discoloration or tarnishing after 50 days.<sup>7,8</sup> In cases where specimens were severely handled after chemical cleaning, finger prints quickly resulted in superficial staining. Under somewhat similar conditions, Cook and Merritt<sup>9</sup> observed a slight tarnish after 15 days of cyclic humidity.

#### Gases

##### Halogens

Beryllium copper is not corroded by fluorine, chlorine, bromine or iodine when perfectly dry at room temperatures, but traces of moisture increase the corrosiveness of these gases. At slightly elevated

TABLE III—Corrosion Resistance of Beryllium Copper in Sea Water

TEST MEDIA*	Temperature, F	Specimen	Duration	Beryllium Content, Percent	Condition and Heat Treatment	CORROSION RATE	
						mdd	ipy
Sea water in Long Island Sound <sup>12</sup>	32-70	Strip, 0.050 x 0.625 x 8 in.	10 mos.	0	Phosphorus deoxidized copper	5.6	0.0009
				2.0	AT (quenched from 1470 F and aged 3 hr at 570 F)	2.3	0.0004
					HT (quenched from 1470 F, cold rolled and aged 2 hr. at 525 F)	2.3	0.0004
Interrupted alternate immersion in sea water <sup>10</sup>	140	Wire	96 hours	0	Not aged	46.5	0.0075
				0.91		46.5	0.0081
		Strip	96 hours	0	Not aged	23.3	0.0037
				1.89		19.4	0.0034
				2.74		3.9	0.0007
3% NaCl solution <sup>20</sup>	59	Strip, 0.039 x 1.18 x 2.36 in.	7 weeks	0	Annealed 1/2 hr. at 1020 F	2.3	0.0004
				2.0	A (quenched from 1510 F)	4.3	0.0008
					AT (quenched from 1510 F and aged 3 hr. at 660 F)	3.4	0.0006
				2.5	A (quenched from 1510 F)	2.0	0.0003
					AT (quenched from 1510 F and aged 3 hr. at 660 F)	2.2	0.0004
				3.5	A (quenched from 1510 F)	2.2	0.0004
					AT (quenched from 1510 F and aged 3 hr. at 660 F)	2.3	0.0004
				0	Annealed 1/2 hr. at 1020 F	3.3	0.0005
				1.5	A (quenched from 1510 F)	4.3	0.0008
					AT (quenched from 1510 F and aged 3 hr. at 660 F)	3.2	0.0006
	113	Strip, 0.039 x 1.18 x 2.36 in.	3 weeks	2.0	A (quenched from 1510 F)	3.6	0.0006
					AT (quenched from 1510 F and aged 3 hr. at 660 F)	3.0	0.0005
				2.5	A (quenched from 1510 F)	2.6	0.0005
					AT (quenched from 1510 F and aged 3 hr. at 660 F)	2.8	0.0005
				3.5	AT (quenched from 1510 F and aged 3 hr. at 660 F)	2.8	0.0005
3% NaCl solution saturated with CuCl	Room	Strip, 0.039 x 1.18 x 2.36 in.	3 weeks	0	Annealed 1/2 hr. at 1020 F	112.1	0.0180
				1.5	A (quenched from 1510 F)	118.8	0.0207
					AT (quenched from 1510 F and aged 3 hr. at 660 F)	107.3	0.0187
				2.0	A (quenched from 1510 F)	100.2	0.0175
					AT (quenched from 1510 F and aged 3 hr. at 660 F)	78.4	0.0137
				2.5	A (quenched from 1510 F)	150.7	0.0263
					AT (quenched from 1510 F and aged 3 hr. at 660 F)	154.9	0.0270
				3.5	A (quenched from 1510 F)	42.9	0.0075
					AT (quenched from 1510 F and aged 3 hr. at 660 F)	51.5	0.0090
Artificial sea water <sup>4</sup>	68	Cast, 0.394 x 0.394 x 0.394 in.	15 days	0.49	As cast	30	0.0052
				1.00	As cast	6	0.0010
				2.05	As cast	3	0.0005
				5.05	As cast	4	0.0007
				9.96	As cast	4	0.0007
Artificial sea water <sup>50</sup>	Room	Strip	168 hours	0	Electrolytic copper	16.9	0.0029
				2.12	H (cold rolled)	15.7	0.0027
					A (quenched from 1480 F)	14.6	0.0025
					AT (quenched from 1480 F and aged 3 hr. at 570 F)	16.2	0.0028

\* Superior figures in this column refer to references at end of article.

temperatures the beryllium content is attacked selectively and lost from the surface of this alloy, apparently because of the high volatility of beryllium halides.<sup>11</sup> Consequently, beryllium copper should be used with caution where exhaust gas from bromine-treated tetraethyl lead gasoline is present.

Good resistance to various organic refrigerants (freon, etc.) has been observed in the absence of moisture. As a result, beryllium copper is frequently employed in refrigeration temperature control equipment.

#### Other Gases

Although moist ammonia may prove corrosive,<sup>12</sup> good results have been observed for beryllium copper feather valves handling moist carbon dioxide.

#### Effect of Elevated Temperature

##### Oxidation and Scaling

As in the case of other copper alloys, the resistance offered by beryllium copper to attack, when heated in an oxidizing atmosphere is largely dependent upon the type of resulting scale. In general, the scale which

forms at elevated temperatures is composed of an outer layer of black cupric oxide ( $\text{CuO}$ ), an intermediate layer of red cuprous oxide ( $\text{Cu}_2\text{O}$ ) and an inner layer of gray-to-colorless beryllium oxide ( $\text{BeO}$ ). Although it is anticipated that beryllium oxide would confer added resistance to oxidation by virtue of its stability, the improvement over pure copper is not impressive due to the presence of less refractory copper oxides.<sup>13,14</sup>

As a result of a new derivation of Wagner's expression, Thomas and Price<sup>15</sup> predicted that oxides with low electrical conductivities should produce films with high oxidation resistance. Since it is generally agreed that the growth of copper oxide films occurs by the diffusion of copper ions outward, it is to be expected that scales preventing or retarding this diffusion (films of low conductivity) will enhance the resistance to oxidation. The electrical conductivities of several oxides are listed in Table XIII.<sup>16,17</sup>

On the basis of this work by Price and Thomas, the oxidation resistance of a number of copper alloys can be approximated. If sufficient beryllium is present in copper to cause the formation of a beryllium oxide film, the rate of oxidation will be reduced approximately 8,000,000 to 1. Froehlich,<sup>18</sup> however, found that the addition of 2.4 percent beryllium to copper reduced the oxidation rate by a factor of about 40 only.

According to the theory advanced by Price and Thomas, the film produced by Froehlich probably was not pure beryllium oxide but contained copper oxide in solution, thereby increasing the electrical conductivity and reducing the oxidation resistance.

Qualitatively, Thomas and Price<sup>19</sup> demonstrated that considerable resistance to tarnishing can be developed by selective oxidation. The treatment suggested for forming a thin beryllium oxide film on the surface calls for 20 minutes heating at 932 F in an atmosphere of hydrogen containing 0.1 mm water vapor. Since this operation would cause rapid overaging of beryllium copper, treatments should be carried out below 600 F if possible. There is no available evidence indicating that this method has been successfully applied in practice. However, it appears to have sufficient merit to warrant consideration.

Under normal conditions, the type of oxide produced depends upon the exposure temperature. Hickman<sup>20</sup> found that both cuprous and cupric oxide are formed at temperatures up to 400 C whereas

TABLE IV—Effect of Immersion in Sulfuric Acid on 2% Beryllium Copper

TYPE OF TEST*	Temperature, F.	Specimen	Duration	Beryllium Content, Percent	Condition and Heat Treatment	CORROSION RATE	
						mdd	lpy
Alternate immersion in 10% solution, 1½ min. in solution and 1½ min. in air <sup>12</sup>	140	Strip, 0.050 x 0.625 x 8 in.	.....	0	Phosphorus deoxidized copper.....	3780	0.609
				2.0	AT (quenched from 1470 F and aged 3 hr. at 570 F)	5115	0.892
					HT (quenched from 1470 F, cold rolled and aged 2 hr. at 525 F)	4880	0.852
Interrupted alternate immersion in 10% solution <sup>10</sup>	140	Strip	96 hours	0 1.89	Not aged.....	1240 1148	0.199 0.198
Continuous immersion in 10% solution <sup>5</sup>	68	Cast, 0.394 x 0.394 x 3.94 in.	24 hours	2.05	As cast.....	100	0.0174
Continuous immersion in 5% sulfuric acid <sup>20</sup>	Room	Strip	24 hours	0	Electrolytic copper.....	30	0.0032
				2.12	H (cold rolled).....	25	0.0044
					A (quenched from 1480 F)	24	0.0042
					AT (quenched from 1480 F and aged 3 hr. at 570 F)	27	0.0047
Continuous immersion in 10% solution <sup>7</sup>	Room	Strip	6 hours	2.1	Apparently rolled, annealed and aged	negligible	.....
			24 hours	2.1	Same.....	31	0.0054
5% sulfuric acid + 3% potassium dichromate	Room	Strip	6 hours	2.1	Same.....	19,840	3.46
			24 hours	2.1	Same.....	18,600	3.24

\* Superior figures in this column refer to references at end of article.

TABLE V—Influence of Beryllium Content in Varying Concentrations of Sulfuric Acid (Loss in mdd)

TEST CONDITIONS**	Beryllium Content, Percent	CONCENTRATION				
		1%	2.5%	5%	7.5%	10%
Interrupted alternate immersion for 96 hours at 140 F on strip specimens (not age hardened) <sup>10</sup>	0	....	....	....	....	1240
	1.89	....	....	....	....	1148
	2.74	....	....	....	....	1244
Continuous immersion for 24 hours at 68 F on cast specimens (not age hardened) <sup>5</sup>	2.99	....	....	....	....	1170
	0.49	180	170	150	120	130
	1.00	110	150	250	130	120
	2.05	160	170	110	140	120
	5.50	90	50	100	80	100
	9.96	20	5	5*	31*	14*

\* Increase in weight, mdd.

\*\* Superior figures in this column refer to references at end of article.

at 500 C both cuprous oxide and beryllium oxide are present and heating to higher temperatures produces only beryllium oxide. Cooling to room temperature from 600 C or higher does not result in any change, since beryllium oxide remains. Similar observations have been reported by other investigators,<sup>21,22</sup> although pressure may exert some influence.<sup>23,24,25</sup> Masing and Dahl<sup>26</sup> were the first to investigate the scaling rate of beryllium copper. They determined the effect of beryllium content on the weight increase resulting from heating for 36 hours at 752 F in a

current of air. As indicated in Figure 5, an increase in beryllium content causes a marked improvement in oxidation resistance.

Subsequently, Froehlich<sup>18</sup> conducted an extensive study of the scaling of pure and alloyed copper in an attempt to determine the direction of the process. In this investigation, Froehlich reaffirmed the increased resistance to scaling with higher beryllium content (see Figure 6). From Froehlich's data, it is also possible to estimate the influence of various additives on the oxidation rate of copper. Figure 7 shows that beryllium is the most effective in this respect, as predicted by Price and Thomas.<sup>15</sup> Froehlich observed a thin external black scale (cupric oxide) which covered a very thin white film (beryllium oxide). Resistance to scaling is attained when this inner film of the solute oxide prevents further diffusion of copper toward the cupric oxide.\*

Terem<sup>27</sup> has carried the investigation of scaling further in include different exposure temperatures and higher beryllium concentrations. The effect of time and temperature upon the oxidation of an alloy in both wire and plate forms containing 2.05 percent beryllium content, indicates that optimum resistance to scaling is obtained with 2 percent beryllium. Terem also observed a whitish layer of beryllium oxide and found that this film afforded substantial protection against corrosion by nitric acid.

Most of the preceding investigation of scaling rate apply to elevated temperatures—temperatures well above the usual operating range for beryllium copper. More recently, Campbell and Thomas<sup>28</sup> determined oxidation curves at more moderate temperatures. The data for beryllium copper strip are reproduced in Figure 10, while Figure 11 presents a comparison of the effect of temperature on the oxidation rate of several materials. The low slope for beryllium copper is in accord with theory, because beryllium will diffuse more readily at higher temperatures, providing a larger proportion of the highly protective beryllium oxide. The role of the diffusion rate on the protection offered by beryllium oxide films also has been considered by Smirnov.<sup>29</sup>

In addition to external scaling, internal oxidation or subscale for-

TABLE VI—Effect of Immersion in Hydrochloric on 2% Beryllium Copper

TYPE OF TEST*	Temperature, F	Specimen	Duration	Beryllium Content, Percent	Condition and Heat Treatment	CORROSION RATE	
						mdd	ipy
Alternate immersion, 1½ min. in solution and 1½ min. in air in 10% HCl <sup>18</sup>	70-75	Strip, 0.050 x 0.625 x 8 in.	.....	0	Phosphorus deoxidized copper	453	0.073
				2.0	AT (quenched from 1470 F and aged 3 hr. at 570 F)	332	0.058
					HT (quenched from 1470 F, cold rolled, and aged 2 hr. at 525 F)	332	0.058
Interrupted alternate immersion in 10% HCl <sup>18</sup>	140	Strip	96 hours	0	Not aged.....	147	0.024
				1.89		182	0.031
Continuous immersion in 3% HCl <sup>18</sup>	Room	Strip, 0.039 x 1.18 x 2.36 in.	7 days	0	Annealed.....	1079	0.174
				2.0	Annealed.....	568	0.099
			2 days	2.0	A (quenched from 1470 F) AT (quenched from 1470 F and aged at 660 F)	629	0.110
				2.5	A (quenched from 1470 F) AT (quenched from 1470 F and aged at 660 F)	707	0.123
Continuous immersion in 1% HCl	Room	Strip, 0.039 x 1.18 x 2.36 in.	7 days	2.0	A (quenched from 1470 F) AT (quenched from 1470 F and aged at 660 F)	400	0.070
				2.5	A (quenched from 1470 F) AT (quenched from 1470 F and aged at 660 F)	449	0.078
Continuous immersion in 1% HCl <sup>18</sup>	68	Cast, 0.394 x 0.394 x 3.94 in.	24 hours	2.0	A (quenched from 1470 F) AT (quenched from 1470 F and aged at 660 F)	402	0.070
				2.5	A (quenched from 1470 F) AT (quenched from 1470 F and aged at 660 F)	656	0.115
Continuous immersion in 10% HCl	68	Cast, 0.394 x 0.394 x 3.94 in.	24 hours	2.05	As cast.....	368	0.064
						585	0.102
Continuous immersion in 3.5% HCl <sup>18</sup>	Room	Strip	24 hours	0	Electrolytic copper.....	56	0.010
				2.12	H (cold rolled).....	42	0.007
					A (quenched from 1480 F)	43	0.007
					AT (quenched from 1480 F and aged 3 hr. at 570 F)	45	0.008

\* Superior figures in this column refer to references at end of article.

TABLE VII—Influence of Beryllium Content in Varying Concentrations of Hydrochloric Acid (Loss in mdd)

TEST CONDITIONS**	Composition*	CONCENTRATION					
		1%	2.5%	3%	5%	7.5%	10%
Continuous immersion for 7 days at room temperature on strip specimens, 0.039 x 1.18 x 2.36 in., in annealed condition <sup>26</sup>	100% Cu	...	...	1079	...	...	...
	1.5% Be	...	...	568	...	...	...
	2.0% Be	...	...	325	...	...	...
	2.5% Be	...	...	400	...	...	...
	3.0% Be	...	...	404	...	...	...
	3.5% Be	...	...	...	...	...	...
	10% Sn	...	...	1168	...	...	...
	12% Sn	...	...	915	...	...	...
	14% Sn	...	...	974	...	...	...
	6% Al	...	...	425	...	...	...
Continuous immersion for 24 hours at 68 F on cast specimens (not age hardened) <sup>3</sup>	8% Al	...	...	586	...	...	...
	0.49% Be	100	50	...	60	90	40
	1.00% Be	80	60	...	60	90	100
	2.05% Be	50	40	...	50	110	90
	5.05% Be	70	160	...	170	130	190
	9.96% Be	30	50	...	60	80	100
Continuous immersion for 24 hours at 68 F on drawn specimens, 0.32 in. diam. x 0.60 in long (not age hardened)	100% Cu	100	70	...	90	100	140
	2.3% Be	70	50	...	50	90	120
	10% Al	40	10	...	60	70	90

\* Balance copper.

\*\* Superior figures in this column refer to references at end of article.

\* The effectiveness of beryllium additions in reducing oxidation rates recently has been confirmed further—see J. P. Dennison and A. Preece, "High-Temperature Oxidation Characteristics of a Group of Oxidation-Resistant Copper-Base Alloys," Journal of the Institute of Metals, Vol. 51, pp. 229-234 (1953).



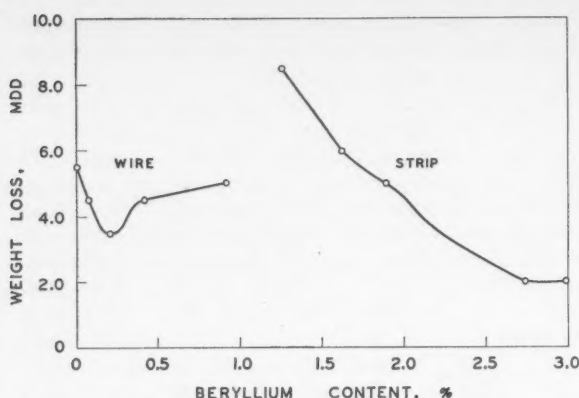


Figure 4—Weight loss resulting from salt spray as affected by beryllium content. Bassett.<sup>(6)</sup>

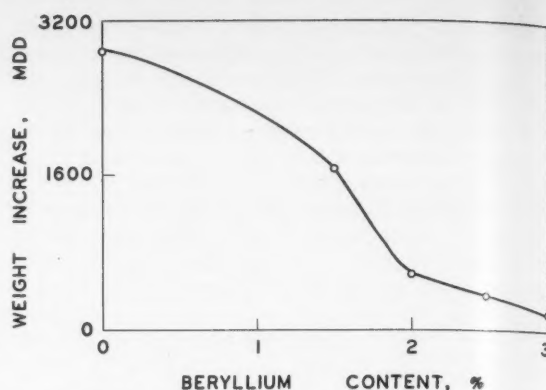


Figure 5—The effect of beryllium content on oxidation rate of beryllium copper strip, 0.040 in. thick, heated 36 hours at 752 F. Masing and Dahl.<sup>(24)</sup>

TABLE VIII—Influence of Beryllium Content in Varying Concentrations of Nitric Acid (Loss in mdd)

TEST CONDITIONS**	Composition*	CONCENTRATION						
		1%	2.5%	3%	5%	6.3%	7.5%	10%
Continuous immersion for 18 days at room temperature on strip specimens, 0.039 x 1.18 x 2.36 in., in annealed condition <sup>20</sup>	100% Cu	...	...	312	...	...	...	...
	1.5% Be	...	...	269	...	...	...	...
	2.0% Be	...	...	285	...	...	...	...
	2.5% Be	...	...	253	...	...	...	...
	3.0% Be	...	...	177	...	...	...	...
	3.5% Be	...	...	251	...	...	...	...
	10% Sn	...	...	215	...	...	...	...
Continuous immersion for 24 hours at 68 F on cast specimens (not age hardened) <sup>5</sup>	12% Sn	...	...	253	...	...	...	...
	14% Sn	...	...	189	...	...	...	...
	6% Al	...	...	184	...	...	...	...
	8% Al	...	...	226	...	...	...	...
	0.49% Be	170	120	...	150	...	170	210
	1.00% Be	90	90	...	90	...	150	110
	2.05% Be	200	150	...	80	...	150	120
Continuous immersion for 24 hours at 68 F on drawn specimens, 0.32 in. diam. x 0.60 in. long (not age hardened)	5.05% Be	6500	12,500	...	24,000	...	28,500	31,500
	9.96% Be	13,500	40,000	...	71,500	...	94,500	94,500
	100% Cu	170	270	...	1070	...	750	500
	2.3% Be	190	370	...	500	...	1210	1320
	10% Al	3410	8530	...	8170	...	11,580	11,050
	10% Cu	...	...	...	...	1695	...	...
	2.12% Be	...	...	...	...	1681	...	...
Continuous immersion for 24 hours at room temperature on strip specimens as follows: <sup>50</sup> Electrolytic copper..... Beryllium copper: H (cold rolled)..... A (quenched from 1480 F).... AT (quenched from 1480 F and aged 3 hr. at 570 F).	2.12% Be	...	...	...	...	1748	...	...
	2.12% Be	...	...	...	...	1928	...	...
	2.12% Be	...	...	...	...	...	...	...
	2.12% Be	...	...	...	...	...	...	...
	2.12% Be	...	...	...	...	...	...	...
	2.12% Be	...	...	...	...	...	...	...
	2.12% Be	...	...	...	...	...	...	...

\* Balance copper.

\*\* Superior figures in this column refer to references at end of article.

TABLE IX—Influence of Beryllium Content in Varying Concentrations of Acetic Acid<sup>1</sup> (Loss in mdd)

TEST CONDITIONS	Beryllium Content, Percent	CONCENTRATION				
		1%	2.5%	5.0%	7.5%	10%
Continuous immersion for 24 hours at 68 F on cast specimens (not age hardened)	0.49	18	20	20	30	40
	1.00	5	20	80	20	30
	2.05	8	20	30	30	40
	5.05	5	30	20	30	20
	9.96	16	20	10	70	10

mation also may result when beryllium copper is heated at relatively high temperatures in the presence of oxygen. The subscale zone generally has a well-defined boundary which moves inward from the metal surface with increasing time of oxidation. The zone consists essentially of isolated particles of beryllium oxide deposited in a matrix of almost pure copper.<sup>50</sup>

Diffusion appears to be the motivating force.

Oxygen diffuses inward from the external surface of the metal to the subscale boundary (reaction front) where it combines with beryllium diffusing outward. On account of its stability, beryllium oxide forms in preference to cuprous oxide. Because beryllium oxide probably has rather limited solubility in copper, it will precipitate within the zone of internal oxidation.

As a result of comprehensive investigations covering dilute binary alloys of beryllium and copper, Rhines<sup>31,32</sup> has established rates for simple internal oxidation and for combined internal and external oxidation. The beryllium contents ran from 0.02 to 0.101 percent, while the temperatures ranged from 1112 to 1832 F. Ternary alloys with zinc, tin or aluminum also were considered.

Figure 12 shows a typical zone of internal oxidation (gray area) resulting from prolonged heating at 1450 F in a salt bath. Note the relatively heavy formations of beryllium oxide appearing as black deposits along the grain boundaries. Figure 13 is similar except that it has been etched to show the base metal more clearly. In both instances, there is a relatively sharp line of demarcation between subscale and unaffected metal.

Although Rhines<sup>33</sup> has called attention to the possible role of internal oxidation in age hardening beryllium copper, it is difficult to obtain this condition. In practice, heating times are too short and temperatures too low to produce this effect.

Meijering and Druyvesteyn<sup>34,35,36</sup> have demonstrated that precipitated beryllium oxide may cause dispersion hardening, depending upon the size of the particles. As a result, the subscale may be slightly harder than pure copper but substantially softer than hardened beryllium copper with a tendency toward brittleness. Consequently, material having internal oxidation could not be expected to withstand severe

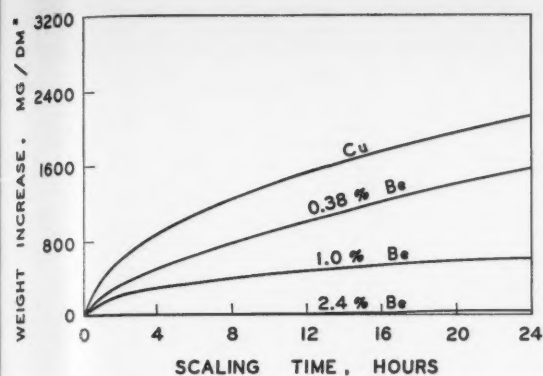


Figure 6—The influence of time and beryllium content on the scaling of beryllium copper strip in a slow air stream at 1472 F. Froehlich.<sup>(18)</sup>

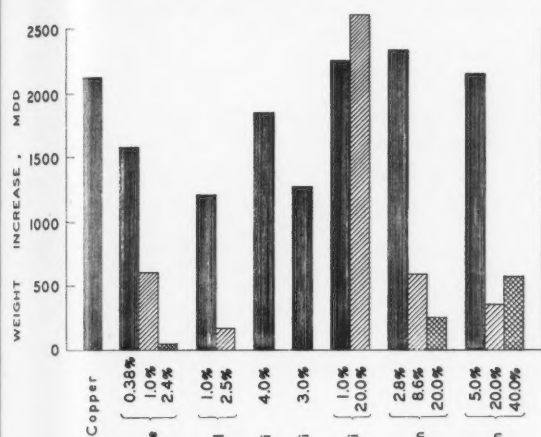


Figure 7—The effect of concentration on the scaling of copper alloys in strip form at 1472 F for 24 hours. Froehlich.<sup>(18)</sup>

operating conditions and would be exceedingly prone to premature failure under dynamic loading.

Although specific data is lacking, it is probable that beryllium copper offers slightly better resistance to attack by sulfur and its gaseous compounds than pure copper. Sulfide or mixed sulfide and oxide scales

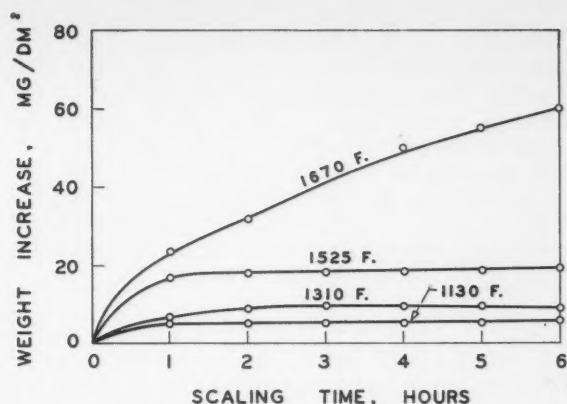


Figure 8—The influence of time and temperature on the scaling of beryllium copper wire and strip (2.05% Be). Terem.<sup>(27)</sup>

result from exposure to atmospheres containing hydrogen sulfide or sulfur dioxide.<sup>37</sup> Price and Thomas<sup>16</sup> have expressed the opinion that selective oxidation of beryllium copper will prevent attack in oxidizing atmospheres containing sulfur.

#### Hydrogen Embrittlement

In further work with dilute solutions of beryllium in copper, Rhines<sup>38</sup> has observed hydrogen embrittlement when specimens were alternately annealed under oxidizing and reducing conditions. Since there is no apparent weakening of the material as evidenced by the bend test data reported, it is probable that structural changes have been observed during metallographic studies.

The mechanism for hydrogen embrittlement proposed by Rhines follows:

1. During the oxidizing cycle, oxygen diffuses into the alloy producing a subscale composed of precipitated beryllium oxide in a matrix of almost pure copper.
2. Subsequent annealing in hydrogen will reduce the beryllium oxide of the subscale, producing water vapor.
3. Since hydrogen diffuses faster through copper than water vapor, sufficient pressure is built up to produce holes along the grain boundary within the oxidized zone.

TABLE X—Corrosion Rates in Phosphoric Acid and Vapor Containing Phosphoric Acid<sup>11</sup>

MATERIAL TESTED	Corrosion Rate Units	3-14% H <sub>3</sub> PO <sub>4</sub> Containing Small Quantity of Fluorine Compounds At 150 F	70-80% H <sub>3</sub> PO <sub>4</sub> Containing Small Quantity of Fluorine Compounds At 185-212 F	70-80% H <sub>3</sub> PO <sub>4</sub> (Dripping) Containing Small Quantities of Fluorine Compounds in a Mist of H <sub>3</sub> PO <sub>4</sub> At 203-230 F	75-80% H <sub>3</sub> PO <sub>4</sub> At 167 F	85-95% H <sub>3</sub> PO <sub>4</sub> (Dripping) Containing Small Quantities of Fluorine Compounds in a Mist of H <sub>3</sub> PO <sub>4</sub> At 212-239 F	85-95% H <sub>3</sub> PO <sub>4</sub> Containing a Small Amount of Fluorine Compounds At 165-185 F	Elemental Phosphorus in Storage At 149-158 F	Vapor Containing a Small Quantity of H <sub>3</sub> PO <sub>4</sub> as a Mist and Traces of Fluorine Compounds At 185-212 F
Beryllium Copper... (2.02 Be, 0.21 Ni)	mdd	12.6	50.2	3368	37.7	354	36.5	6.8	263
Phosphor Bronze-C... (8% Sn)	ipy	0.0022	0.0088	0.5900	0.0066	0.0620	0.0064	0.0012	0.0460
Copper... (99.9% Cu)	mdd	0.0018	0.0110	0.8000	0.0066	0.1120	0.0084	0.0011	0.0870
	ipy	5.6	83.9	4039	62.1	338	136.8	7.5	398
		0.0009	0.0135	0.6500	0.0100	0.0830	0.0220	0.0012	0.0640
Aluminum Bronze... (5% Al)	mdd	...	...	...	1451	...	...	...	1709
	ipy	...	...	...	0.2550	...	...	...	0.3000
High Brass... (35% Zn)	mdd	25.9	142	578	106	802	118	4.1	318
	ipy	0.0044	0.0240	0.980	0.0180	0.1360	0.0200	0.0007	0.0540
Cupro-Nickel... (20% Ni, 5% Zn)	mdd	17.3	48.4	4378	148	272	43.2	5.6	197
	ipy	0.0028	0.0080	0.7100	0.0240	0.0440	0.0070	0.0009	0.0440
Silicon Bronze... (3.1% Si, 1.1% Mn)	mdd	29.7	41.6	416	32.1	262	32.7	7.1	190
	ipy	0.0050	0.0070	0.0700	0.0054	0.0440	0.0055	0.0012	0.0320
Monel... (2.9% Cu)	mdd	17.2	369	...	148	461	86.1	4.9	274
	ipy	0.0028	0.0600	...	0.0240	0.0750	0.0140	0.0008	0.0445
Mild Steel... (0.24% C)	mdd	170	Excessive	...	18.720	...	45.500	21.9	197
	ipy	0.0310	Excessive	...	3.4200	...	8.3100	0.0040	0.0360

In practice, hydrogen embrittlement has not been observed in commercial beryllium copper alloys of higher beryllium content (over 1 percent). The absence of this phenomenon is perhaps due to the difficulty in producing subscale during normal operating procedures. In addition, it is doubtful whether it is possible to reduce beryllium oxide with hydrogen even at temperatures as high as the melting temperature of beryllium copper. Consequently, if hydrogen embrittlement does occur, some other reaction must be responsible.

#### Liquid or Molten Metals

In contact with liquid metals, the usefulness of beryllium copper is determined by its resistance to alloying (solid solution or intermetallic compound formation), intergranular penetration, selective attack of surface beryllium, and chemical compound (oxide) formation. Kelman and co-workers<sup>39</sup> have reported good resistance to attack by mercury up to 200 F, with limited usefulness in the range 200-700 F. Good resistance is also offered to sodium, potassium and sodium-potassium alloys, at least to 1112 F.

On the basis of poor resistance provided by copper,<sup>39</sup> it is anticipated that beryllium copper would not be suitable in connection with gallium, lead, bismuth, eutectic bismuth-lead, tin, thallium, indium, cadmium, lithium or aluminum in their molten states.

From an application standpoint, beryllium copper plunger tips are extensively used in aluminum die casting, while pressure-cast beryllium copper dies

TABLE XIII—Electrical Conductivity of Several Oxides  
Price and Thomas<sup>10</sup>

OXIDE	Conductivity, $\frac{\text{mhos}}{\text{cm}^2}$		
	At 1000 C	At 500 C	At 0 C
BeO.....	$10^{-9}$	very small	very small
Al <sub>2</sub> O <sub>3</sub> .....	$10^{-7}$	very small	very small
SiO <sub>2</sub> .....	$10^{-6}$	$10^{-9}$	.....
MgO.....	$10^{-5}$	$10^{-8}$	very small
TiO <sub>2</sub> .....	$10^{-4}$	.....	.....
SnO <sub>2</sub> .....	$10^{-2}$	.....	.....
NiO.....	$10^{-2}$	$10^{-4}$	.....
Cr <sub>2</sub> O <sub>3</sub> .....	$10^{-1}$	$10^{-2}$	$10^{-4}$
Fe <sub>2</sub> O <sub>3</sub> .....	$10^{-1}$	$10^{-4}$	.....
ZnO.....	1	.....	$10^{-4}$
Cu <sub>2</sub> O.....	$10^{+1}$	$10^{-1}$	.....
CuO.....	$10^{+1}$	$10^{-2}$	$10^{-6}$
FeO.....	$10^{+2}$	.....	.....

TABLE XIV—Galvanic Series Based Upon Potential Measurements  
in Artificial Sea Water at 77 F Against Calomel Half Cell.<sup>7</sup>

METAL OR ALLOY	Potential in Volts
Magnesium and alloys.....	-1.60
Zinc and alloys.....	-1.05 to 1.10
Zinc plating on steel.....	.....
Cadmium.....	-0.75 to 0.80
Aluminum and alloys.....	-0.62 to 0.80
Tin.....	-0.62
Lead.....	-0.61
Iron.....	-0.46 to 0.58
Carbon steel.....	.....
Tin/lead solders.....	-0.50
Brass.....	.....
Copper.....	.....
Bronze.....	-0.22 to 0.28
Nickel silver.....	.....
Cupro-nickel.....	.....
Beryllium copper.....	-0.20
Silver.....	+0.02
Gold.....	+0.06
Platinum.....	+0.10
Rhodium.....	.....

TABLE XI—Influence of Beryllium Content in Varying Concentrations of Sodium Hydroxide  
(Loss in mdd)

TEST CONDITIONS*	Beryllium Content, Percent	CONCENTRATION					
		1%	2.5%	4%	5%	7.5%	10%
Continuous immersion for 24 hours at 68 F on cast specimens (not age hardened) <sup>8</sup>	0.49	120	210	...	139	40	30
	1.00	60	200	...	130	61	21
	2.05	70	188	...	121	78	30
	5.05	90	210	...	139	100	21
	9.96	80	118	...	50	20	30
Continuous immersion for 24 hours at room temperature on strip specimens as follows: <sup>30</sup>	Electrolytic copper.....	0	...	9.4	...	...	...
	Beryllium copper:						
	H (cold rolled).....	2.12	...	10.6	...	...	...
	A (quenched from 1480 F).....	2.12	...	7.7	...	...	...
	AT (quenched from 1480 F) and aged 3 hr. at 570 F).....	2.12	...	11.6	...	...	...

\* Superior figures in this column refer to references at end of article.

TABLE XII—Influence of Beryllium Content in Varying Concentrations of Ammonium Hydroxide  
(Loss in mdd)

TEST CONDITIONS*	Beryllium Content, Percent	CONCENTRATION					
		1%	2.5%	3.5%	5%	7.5%	10%
Continuous immersion for 24 hours at 68 F on cast specimens (not age hardened) <sup>8</sup>	0.49	910	830	...	660	720	710
	1.00	680	850	...	530	550	530
	2.05	730	540	...	560	550	540
	5.05	540	390	...	820	380	370
	9.96	420	510	...	510	330	290
Continuous immersion for 24 hours at room temperature on strip specimens as follows: <sup>30</sup>	Electrolytic copper.....	0	...	88	...	...	...
	Beryllium copper:						
	H (cold rolled).....	2.12	...	60	...	...	...
	A (quenched from 1480 F).....	2.12	...	60	...	...	...
	AT (quenched from 1480 F and aged 3 hr. at 570 F).....	2.12	...	62	...	...	...

\* Superior figures in this column refer to references at end of article.

are sometimes employed in die casting zinc. In the former application, attack is steady but is not rapid enough to prevent successful use. In the latter case, the dies will eventually wash but have proven economical for short or moderate runs.

#### Galvanic Corrosion

In the absence of specific data on the galvanic corrosion of beryllium copper, it must be assumed that it will behave like pure copper in this respect. As a result, it may be safely coupled to other copper alloys. Tests conducted with beryllium copper in contact with copper in a salt spray for one month, indicate that the weight loss is no greater than normally encountered with beryllium copper alone under similar test conditions.<sup>10</sup>

Table XIV lists the contact potentials of various metals.<sup>7</sup> These values, which are the potentials of the individual metals immersed in artificial sea water at 77 F measured against a normal calomel half cell, should be used only as a guide



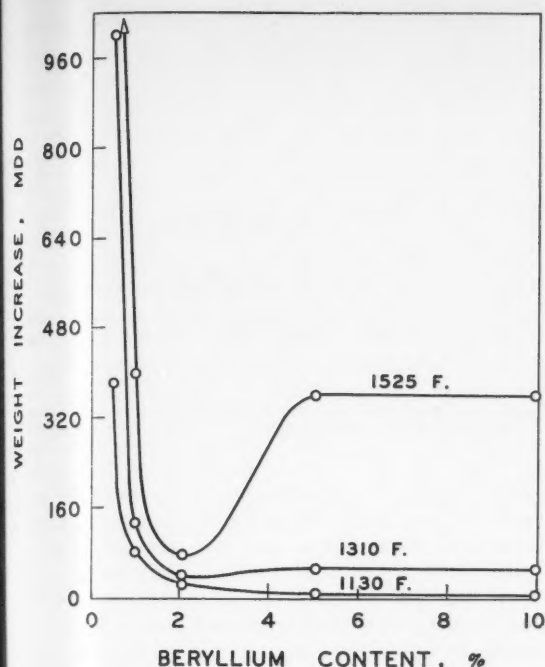


Figure 9—The effect of beryllium content and temperature upon the oxidation rate of beryllium copper exposed for 6 hours. Terem.<sup>(27)</sup>

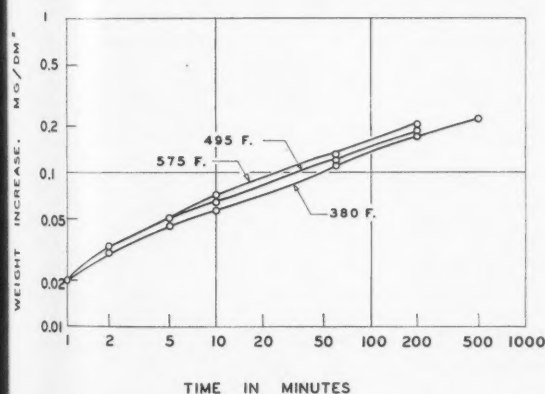


Figure 10—Oxidation curves for beryllium copper half-hard strip, 0.005 in. thick and nominally 2% Be. Campbell & Thomas.<sup>(28)</sup>

in view of the many variables usually present. For example, Tracy<sup>12</sup> observed in a potential test in sea water that beryllium copper was anodic to phosphorus deoxidized copper by 50 millivolts when both metals were immersed, but within 24 hours the potential was reversed and beryllium copper was cathodic by 50 millivolts.

When it is necessary to connect beryllium copper galvanically with zinc, aluminum or magnesium under corrosive conditions, some means of insulation should be considered to prevent accelerated corrosion of these latter materials. Under certain conditions it may be desirable to plate beryllium copper with tin for contact with aluminum alloys or with zinc or cadmium for use against zinc alloys. In the case of iron or steel, where the potential difference would be less, galvanic action would probably only be en-

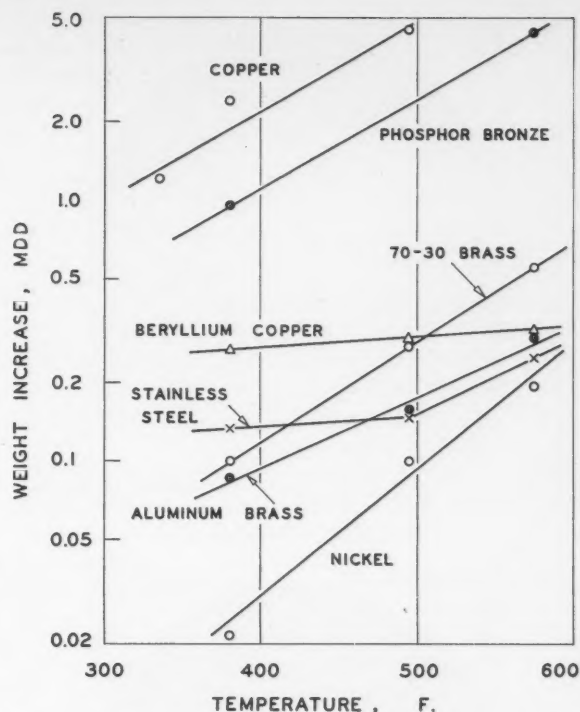


Figure 11—Effect of temperature on the oxidation rates of several strip materials, 0.005-inch thick, exposed for one hour. Campbell & Thomas.<sup>(28)</sup>

countered in the case of relatively large areas of beryllium copper.

### Mechanical Factors

In the field, corrosion phenomena are frequently complicated by mechanical factors. Since mechanical action generally increases corrosion rates, often to a high degree, its effect must be carefully considered. Types discussed include stress-corrosion and cavitation-erosion. Stress-corrosion can be further divided, depending upon the nature of the stress, to give stress-corrosion-cracking (static stress) and corrosion-fatigue (dynamic stress).

### Stress Corrosion Cracking

In stress-corrosion-cracking, stresses may be either induced (service loading) or internal (fabricating). The term "season cracking" can be considered as a

TABLE XV—Characteristics of Beryllium Copper Alloys Subjected to Stress Corrosion on Tests<sup>40</sup>  
(See Figure 14)

	ALLOY DESIGNATION	
	A	B
<b>Chemical composition:</b>		
Beryllium.....	1.37	0.71
Cobalt.....	.....	1.45
Manganese.....	1.56	.....
Iron.....	0.15	.....
Copper.....	96.92	97.84
<b>Mechanical properties:</b>		
Tensile strength, psi.....	87,800	53,800
Yield strength, psi.....	72,200	26,000
Elastic limit, psi.....	58,500	17,000
Elongation in 2 in., percent.....	14	25
Rockwell hardness.....	B42-55	B68-83

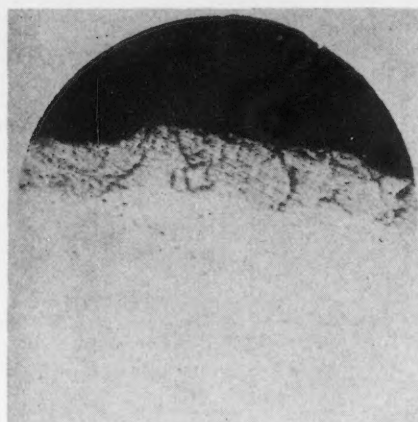


Figure 12—Internal oxidation (gray area) resulting from prolonged heating in salt bath at 1450 F. Note distinct boundary between sub-scale and normal material (light area). No etch (magnified 500 X).

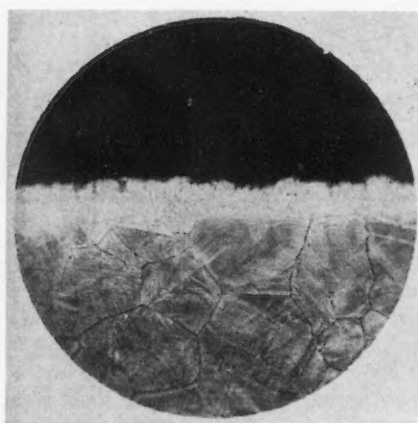


Figure 13—Internal oxidation similar to Figure 12 but etched to show base metal. Ammonium persulfate etch (magnified 500 X).

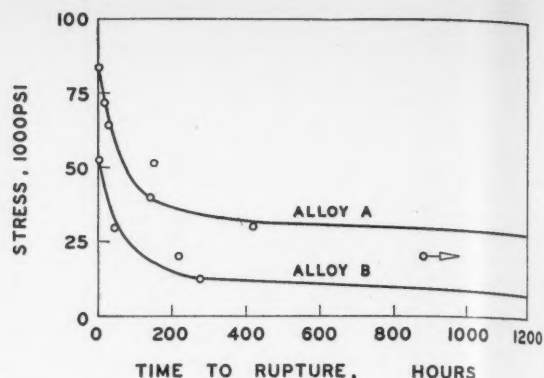


Figure 14—Stress-rupture characteristics of beryllium copper in ammonia atmosphere (non-standard alloys, see Table XV). Clenny.<sup>40</sup>

special type of stress-corrosion resulting from internal or residual stresses and is usually applied to brasses containing less than 85 percent copper.

It is probable that stress-corrosion-cracking can be produced in almost all metals and alloys under certain combinations of stress, time and corrosives. Detailed data for beryllium copper are unavailable; however, field reports indicate excellent resistance. The only known published figures result from Clenny<sup>40</sup> and cover non-standard casting alloys (see Figure 14 and Table XV). In view of the low tensile and hardness properties shown (approximately 50-65% of anticipated), specimens may have been tested in the "as cast" conditions, without the usual solution and aging treatments.

#### Corrosion-Fatigue

Corrosion-fatigue combines dynamic or cyclic stresses with corrosion. Damage from this form of attack can be especially severe, since the roughened or pitted surface resulting from corrosion increases the rate of crack propagation due to dynamic loading. In many cases the protective oxide films which form on corrosion-resistant materials are rendered useless by virtue of cyclic stressing.

Among available alloys, beryllium copper provides unusual resistance to corrosion-fatigue. Tests conducted in salt spray solutions indicate that the normal endurance of this material is not appreciably lowered under corrosive conditions. The results of several corrosion fatigue studies on beryllium copper in various forms are listed in Table XVI, while Figure 15 compares several materials on the basis of their relative resistance to corrosion-fatigue. The comparative data presented is based on average values obtained from a number of references.<sup>41,47</sup>

TABLE XVI—Summary of Corrosion Fatigue Data for Beryllium Copper

	Gough and Sopwith <sup>41</sup>	Sopwith <sup>42</sup>	Stewart and Williams <sup>43</sup>					
Corrosive media.....	3% salt in distilled water		Brackish water (1/6-1/3 salinity of sea water)					
Type test.....	Rotating beam, 2200 RPM		Rotating beam, 1450 RPM					
Composition								
Beryllium.....		2.25	2.36	2.91	0.31	0.53		
Nickel.....		0.30	2.42	.....	1.64	.....		
Cobalt.....		.....	.....	.....	.....	2.85		
Iron.....		0.10	0.02	0.10	0.13	0.32		
Magnesium.....		.....	0.33	0.33	0.16	0.16		
Copper.....		97.26	95.09	97.04	97.91	96.46		
Form.....	Rod		Cut from cast test blocks, 2 in. x 12 in. x 12 in.					
Condition	Cold drawn	Solution treated	Solution treated and aged 1 hr. at 680 F	Solution treated and aged 4 hr. at 660 F	Solution treated and aged 4 hr. at 525 F	Solution treated and aged 4 hr. at 575 F	Solution treated and aged 2 hr. at 750 F	Solution treated and aged 2 hr. at 930 F
Mechanical properties:								
Tensile strength, psi.....	93,600	72,100	182,000	107,800	150,000	119,600	32,100	49,000
Proportional limit, psi.....	30,700	12,100	53,800	40,000	51,500	83,500	.....	24,000
Rockwell hardness.....	B87	B68	C42	C34	C40	C42	B97	B93
Fatigue strength at 50,000,000 cycles:								
In air, psi.....	36,500	35,800	43,500	13,000	17,500	15,500	8,000	7,000
In salt water or spray, psi.....	39,000	30,500	35,600	12,500	13,500	15,500	7,700	7,000

Cavitation-Erosion

Cavitation-erosion may be defined as the damage of a material associated with the formation and collapse of cavities in the liquid at a solid-liquid interface.<sup>48</sup> Flow irregularities produce low-pressure areas, allowing pockets of vapor to form. The collapse of these cavities or pockets, due to abrupt flow or pressure changes, causes high shock pressures in localized areas, leaving a roughened surface.

Several test methods have been devised to simulate cavitation-erosion conditions. In addition to the corrosion-fatigue tests conducted by Stewart and Williams<sup>49</sup> and listed in Table XVI, several of the same beryllium copper alloys in cast form were exposed to vibratory hydraulic cavitation tests in sea water under laboratory conditions. Relative resistances for these alloys are shown in Table XVII. As in the original paper,<sup>43</sup> relative resistance is the ratio of weight loss for a standard manganese bronze sample (1.00) to the weight loss for the test material.\* The beryllium contents afford a comparison with other data given in Table XVI.

Conclusions

From the corrosion data presented, it is possible to consider corrosion problems encountered in processing and service. Perhaps the most important factor from a processing standpoint is the effect of heat treatment upon surface condition. Obviously the solution treatment (up to 3 hours at 1475 F) would be more severe than age hardening (up to 3 hours at 550-750 F). Unless prevented by controlled atmospheres, scaling will occur during both operations. In addition to heavier scaling during solution treating, beryllium oxide will also form at the temperatures involved. This oxide will present special problems in subsequent machining, pressworking, plating or joining—unless removed.

Similarly, beryllium oxide can be expected to present service problems. For example, its low electrical conductivity means high contact resistance. In addition, it may cause premature wear in mating parts. On the other hand, beryllium oxide films may impart special resistance to certain corrosive environments or be the answer to critical wear problems. Consequently, all processing and service requirements should be carefully weighed in determining whether the beryllium oxide film is an asset. Safety tools perhaps represent the most familiar application of beryllium copper where corrosion presents a problem. In addition to the nonsparking feature, these tools also provide the resistance to corrosion needed in many marine, petroleum and chemical operations. Beryllium copper scraper blades, springs, shaft seals and a host of other components find use in chemical processing equipment. Instrument springs as well as bellows, diaphragms and bourdon tubes are exposed to atmospheres ranging from polar to tropic and rural to industrial. Beryllium copper reed and flapper valves employed in outboard motors are subjected simultaneously to fatigue load-

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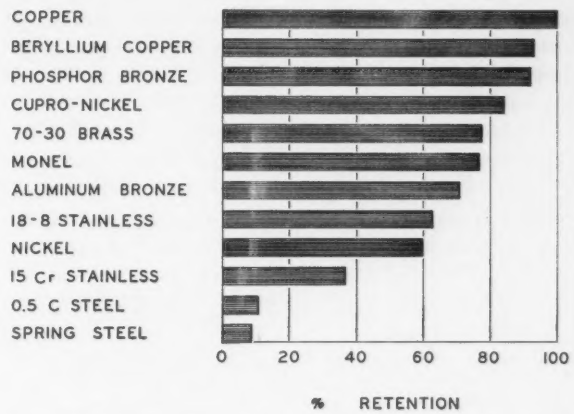


Figure 15—Relative corrosion fatigue of several materials based upon retention in salt spray of normal endurance properties.<sup>(41-47)</sup>

TABLE XVII—Relative Resistance of Beryllium Copper Casting Alloys to Hydraulic Cavitation Tests<sup>42</sup>  
(Vibration Time—120 Minutes)

ALLOY	Composition	Condition	Tensile Strength, psi	Relative Resistance to Cavitation Erosion
Manganese Bronze	41 Zn, 0.29 Mn, 1.1 Fe	As cast	73,200	1.00
Cu-Co-Be.....	0.53 Be, 2.85 Co	Heat Treated	49,000	0.78
Cu-Be.....	2.91 Be	As cast	107,800	1.83
Cu-Ni-Be.....	2.36 Be, 2.48 Ni	Heat Treated	150,000	2.48
Cu-Be.....	2.91 Be	Heat Treated		6.00

TABLE XVIII—Corrosion Resistance of Beryllium Copper Summarized

Approximate Service Ratings (see note)		
Good	Limited	Poor
Acetic acid, 0.1% (RT)	Acetic acid, 2.5-10% (RT)	Aluminum, molten
Alcohols	Bromine, moist (RT)	Ammonia, moist
Alum	Chlorine, moist (RT)	Ammonium hydroxide
Ammonia, dry	Fluorine, moist (RT)	Bismuth, molten
Atmosphere, rural	Hydrochloric acid, 0-5% (RT)	Bismuth-lead eutectic, molten
marine	Mercury (200-700 F)	Bromine, moist (ET)
industrial	Mine water	Cadmium, molten
Boric acid	Phosphoric acid, 3-95% (RT-212 F)	Chlorine, moist (ET)
Brines	Sea water (140 F)	Chromic acid
Bromine, dry	Sodium chloride, 3% + copper chloride	Ferric chloride
Calcium chloride	Sodium hydroxide, 1-10% (RT)	Fluorine, moist (ET)
Carbon dioxide, dry or moist	Sulfur dioxide, moist	Gallium, molten
Carbon tetrachloride	Sulfuric acid, 0-10% (RT)	Hydrochloric acid, 10% (140 F)
Chloride, dry	Zinc, molten	Hydrochloric acid, over 5% (RT)
Citric acid		Hydrogen sulfide, moist
Fluorine, dry		Indium, molten
Freon		Lead, molten
Fresh water		Lithium, molten
Gasoline		Nitric acid
Hydrocarbons		Sulfuric acid, 10% (140 F)
Hydrogen sulfide, dry		Sulfuric acid, 5% + potassium dichromate, 3%
Ketones		Thallium, molten
Mercury (RT-200 F)		Tin, molten
Oxalic acid		
Phosphorus (150 F)		
Potassium, molten (up to 1112 F)		
Sea water (RT)		
Sodium chloride		
Sodium, molten (up to 1112 F)		
Sodium-potassium alloys, molten (up to 1112 F)		
Steam		
Sulfur dioxide, dry		
Tannic acid		
Trichlorethylene		

RT—room temperature ET—elevated temperature  
Note: These ratings, based upon laboratory and field tests, are offered only as a guide, since corrosion rates are affected by agitation, temperature, aeration, concentrations, etc. Ratings based upon laboratory tests have the following significance:  
Rating      Rate of attack, tpy  
Good      less than 0.001  
Limited      0.001 to 0.010  
Poor      more than 0.010

\*A high value indicates improved resistance for decreased weight loss.



ing and salt water impingement. Many other equally severe applications can be cited.

To combat certain types of corrosion, it may be desirable to lacquer or plate beryllium copper components. Many types of plating, including gold, silver, tin, zinc, cadmium, copper, nickel and chromium can be applied readily where needed.<sup>49</sup>

The accompanying Table XVIII summarizes the corrosion resistance of beryllium copper to various media under normal conditions. Data are based upon laboratory tests and service experience. This table is offered only as a guide or starting point—to be supplemented by tests under actual operating conditions whenever possible.

### References

1. J. T. Richards. Beryllium Copper. *Mat. and Meth.*, **31**, No. 4, 75-90 (1950) April.
2. Otto Dahl. On the Resistance to Corrosion of Bronzes. *Korrosion. Bericht über die III. Korrosionstagung*, 23-36 (1933).
3. The Corrosion of Metals. Part VI. The Corrosion of Copper and Its Alloys, *Sheet Metal Ind.*, **24**, 145-151 (1947) January.
4. P. E. Bojkov. Use of Beryllium in Copper-Base Alloys for Reliable Castings. *Liteinoe Delo.*, **8**, 23-31 (1937).
5. Haldun N. Terem. The Corrosion of Beryllium Bronzes. *Bull. de la société chimique de France*, **4**, 1509-1524 (1937); also *Comptes rendus*, **204**, 1426-1428 (1937).
6. L. D. Yates. Corrosion Tests of Metals and Ceramics. Tennessee Valley Authority, Wilson Dam, Alabama, Chemical Engineering Report No. 9 (1951), 56 pp.
7. Pickling and Electroplating Beryllium Copper Alloy Components. *Prod. Fin.*, **16**, 22-48 (1951) Nov.
8. E. E. Halls. Plating and Pickling Beryllium-Copper Components. *Metallurgia*, **39**, 181-186 (1949) February.
9. C. D. Cook and C. Merritt, Jr. Materials and Finishes for Tropical Services. *Mat. and Meth.*, **25**, No. 5, 77-80 (1947) May.
10. W. H. Bassett. Beryllium Copper Alloys. *Trans. Amer. Inst. Mining and Met. Eng.* **75a**, 218-232 (1927).
11. Anaconda Beryllium Copper. American Brass Co., Publication B-21 (1941), p. 12.
12. A. W. Tracy. Corrosion of Copper-Beryllium Alloys. Section from Corrosion Handbook, John Wiley & Sons, Inc., New York (1948) pp. 110-112.
13. U. R. Evans. Tarnishing and Related Phenomena. *Sheet Metal Ind.*, **24**, 2189-2205 (1947) Nov.
14. R. F. Tylecote. Review of Published Information on the Oxidation and Scaling of Copper and Copper-Base Alloys. *Inst. Metals*, **78**, 259-300 (1950) Nov.
15. G. J. Thomas and L. E. Price. Selective Oxidation as a Fundamental Principle in Metallic Protection. *Nature*, **141**, 830-831 (1938).
16. L. E. Price and G. J. Thomas. Oxidation-Resistance in Copper Alloys. *J. Inst. Metals*, **63**, 21-28 (1938).
17. L. E. Price and G. J. Thomas. Oxidation-Resistance in Copper Alloys. *Metal Ind.*, **53**, 413-416 (1938) Oct.
18. Karl Wilhelm Froehlich. The Scaling of Pure and Alloyed Copper. *Zeitschrift für Metallkunde*, **28**, 368-375 (1936) Dec.
19. G. J. Thomas and L. E. Price. Preventing Oxidation and Tarnishing. *Metal Ind.*, **54**, 189-190 (1939) Feb.
20. J. W. Hickman. Oxide Films Formed on Metals and Binary Alloys. An Electron Diffraction Study. *Trans., Amer. Inst. Mining and Met. Eng.*, **180**, 547-564 (1948) Dec.; also Proceedings, Pittsburgh International Conference on Surface Reactions, Corrosion Publishing Co., Pittsburgh (1948), pp. 142-156.
21. Ichiro Iitake and Shizuo Miyake. Oxide Films of Some Alloys. *Nature*, **137**, 457 (1936).
22. Shizuo Miyake. A Study of Oxide Films on Metal Surface with Cathode-Ray Diffraction. I. Copper and Its Alloys. *Bull. Inst. Phys. Chem. Res.*, **14**, 704-713 (1935); also *Scientific Papers of the Inst. Phys. Chem. Res.*, **29**, 167-178 (1936) July.
23. K. One, S. Yoshida and I. Takeda. Study of Cu-Be Alloy by Electron Diffraction Method. *Materials for the Researches of the Electrical Communication Laboratory*, No. 3, 1-12 (1949) Dec.
24. Kazumasa Ono. "Study of Cu-Be (Be 3%) Alloy by Electron Diffraction Method. *Materials for the Researches of the Electrical Communication Laboratory*, No. 13, 1-14 (1950) Dec.
25. K. Ono, S. Yoshida and I. Takada. Selective Oxidation of Alloys. *J., Inst. of Met. (Japan)*, **15B**, 55-57 (1951).
26. Georg Masing and Otto Dahl. Physical Properties and Age-Hardening of Beryllium copper Alloys. *Wissenschaftliche Veröffentlichungen aus dem Siemens-Konzern*, **8**, 101-125 (1929); also Beryllium—Its Production and Application. Translation by Richard Rimbach and A. J. Michel, Reinhold Publishing Corp., New York (1932), pp. 121-150.
27. Haldun N. Terem. Oxidation of Beryllium Bronzes. *Bull. société chimique de France*, **5**, 589-600 (1938); also *Comptes rendus*, **205**, 47-49 (1937).
28. W. E. Campbell and U. B. Thomas. The Oxidation of Metals. *Trans., Electrochem. Soc.*, **91**, 623-39 (1947).
29. A. Smirnov. A Theory of the Oxidation of Alloys. *Acta Physicochimica (U.S.S.R.)*, **22**, 162-186 (1947).
30. F. N. Rhines. Internal Oxidation. *Corrosion and Mat. Prot.*, **4**, 15-20 (1947) Mar.-Apr.
31. F. N. Rhines. A Metallographic Study of Internal Oxidation in the Alpha Solid Solutions of Copper. *Trans., Amer. Inst. Min. Met. Eng.*, **137**, 246-290 (1940).
32. F. N. Rhines, W. A. Johnson and W. A. Anderson. Rates of High-Temperature Oxidation of Dilute Copper Alloys. *Trans., Amer. Inst. Min. Met. Eng.*, **147**, 205-220 (1942).
33. F. N. Rhines. Available Beryllium Reduced by Internal Oxidation. *Metal Prog.*, **47**, 282 (1945) Feb.
34. J. L. Meijering and M. J. Druyvesteyn. Hardening of Metals by Internal Oxidation. *Philips Research Reports*, **2**, 81-102 (1947) April; 260-280 (1947) Aug.
35. J. L. Meijering. Some Aspects of Internal Oxidation in Silver, Copper, Nickel and Iron Alloys. Proc., Pittsburgh International Conference on Surface Reactions, Corrosion Publishing Co., Pittsburgh (1948), pp. 101-104.
36. J. L. Meijering. Some Aspects of Internal Oxidation in Silver, Copper, Nickel and Iron Alloys. Report of Conference on Strength of Solids, Physical Society, London (1948), pp. 140-151.
37. F. N. Rhines. Copper and Copper Alloys, Section from Corrosion Handbook, John Wiley & Sons, Inc., New York (1948), pp. 621-630.
38. F. N. Rhines and W. A. Anderson. "Hydrogen Embrittlement of Pure Copper and of Dilute Copper Alloys by Alternate Oxidation and Reduction. *Trans., Amer. Inst. Min. Met. Eng.*, **143**, 312-325 (1941).
39. LeRoy R. Kelman, Walter D. Wilkinson and Frank L. Yaggee. Resistance of Materials to Attack by Liquid Metals. Chapter from Liquid-Metals Handbook, Office of Naval Research, Washington, June 1 (1950), pp. 77-126.
40. J. T. Clenny. Stress Corrosion. *Iron Age*, **167**, 85-89 (1951) June 21.

41. J. H. Gough and D. G. Sopwith. Resistance of Some Special Bronzes to Fatigue and Corrosion Fatigue. *J. Inst. Metals*, **60**, 143-158 (1936).
42. D. G. Sopwith. The Resistance of Aluminum and Beryllium Bronzes to Fatigue and Corrosion Fatigue. Aeronautical Research Council, Report and Memoranda No. 2486 (1951).
43. W. C. Stewart and W. L. Williams. Investigation of Materials for Marine Propellers. *Proc., Amer. Soc. Test. Mat.*, **46**, 836-845 (1946).
44. R. A. Wilkins and E. S. Bunn. Copper and Copper Base Alloys. McGraw-Hill Book Co., New York (1943).
45. D. J. McAdam, Jr. Corrosion-Fatigue of Non-Ferrous Metals. *Proc., Amer. Soc. Test. Mat.*, **27** II, 102-127 (1927).
46. D. J. McAdam, Jr. Fatigue and Corrosion-Fatigue of Spring Materials. *Trans., Amer. Soc. Mech. Eng.*, **51**, 45-58 (1929).
47. Blaine B. Westcott. Corrosion-Fatigue. Section from Corrosion Handbook, John Wiley & Sons, Inc., New York (1948), pp. 578-590.
48. Corrosion Handbook, John Wiley & Sons, Inc., New York (1948), pp. xxvi.
49. J. T. Richards. How to Work With Beryllium Copper Strip. *Amer. Mach.*, **96**, 99-114 (1952) March 31.
50. Kenzo Inamura and Hidekichi Ohashi. Some Properties of Beryllium Bronzes. *Sumitomo Kinzoku Kogyo Kenkyu Hokoku*, **2**, 656-668 (1936).

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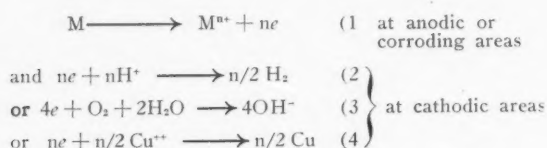
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# Interpretation and Significance Of Potentials of Metals in Aqueous Solutions\*

By MORRIS COHEN\*

THE POTENTIALS of metals have been used widely in interpreting the behavior of metals in solutions.<sup>1,2</sup> This is quite natural because it is now a generally accepted fact that the corrosion of metals in an aqueous environment is electrochemical in nature. This means that there are two electrode reactions taking place at cathodic and anodic areas separated from one another. In corroding systems these two reactions are not the reverse of each other but are generally two different reactions such as:



The metal-metal ion reaction determines the potential of the anodic areas and the cathodic reaction (or reactions) determines the potential of the cathodic areas. These potentials are commonly based on the voltage of hydrogen being equal to zero and this is the reference used in this presentation.

Because a corroding system is obviously not at equilibrium the potentials measured are not equilibrium potentials but are those of more or less polarized electrodes. The corrosion rate will depend on the usual factors which determine reaction rates and these factors can be given equivalent electrochemical terms as follows:

## Anodic Reaction

Chemical	Electrochemical
Concentration of reactants	Equilibrium potential
Diffusion	Concentration Polarization
Activation Energy	Overvoltage

The same set of terms is true for the cathodic reaction and

$$I = \frac{E_c - E_a}{\Sigma R}$$

where  $I$  is the current,  $E_c$  is the potential of the cathodes,  $E_a$  is the potential of the anodes and  $\Sigma R$  is the sum of all the resistance paths in the electrical circuit of the corroding system. While it is usually possible to postulate many reactions in a corroding system, those reactions with the smallest amount of polarization with increasing current density will predominate.

## Abstract

The potential of a metal in an aqueous solution is dependent both on the reaction or reactions which are taking place between the metal surface and the environment and on the physical nature of the system. When a metal is corroding not only is the system not in equilibrium but there is usually more than one reaction taking place. The potential which is measured is therefore a mixed polarized potential. Because of this, the measured potential is a poor criterion of the corrosion resistance and must be considered in relation to the environment. The effect of the resistance paths in the system on the potentials are considered. Examples of the potentials of iron in various systems are given and the main factors determining these potentials are outlined.

The equilibrium potential of a metal/metal-ion electrode depends on the concentration of the reacting ions in a very definite manner, as given by the Nernst Equation.

$$E = E_0 + \frac{RT}{nF} \ln (M^{n+}) = E_0 + \frac{0.059}{n} \log (M^{n+})$$

where  $E_0$  is the standard electrode potential,  $n$  is the valency of the metal ion,  $(M^{n+})$  is the activity of the metal ion in the solution, and  $F$  is Faraday's constant. If the metal corrodes to form an insoluble product, as iron does in most neutral solutions, the ionic concentration is determined by the solubility product of the precipitate. Potential measurements have been used to determine the solubility product of ferrous hydroxide in oxygen free solutions.<sup>3</sup> When the concentration of the metal ion falls below about  $10^{-6}N$  the Nernst equation usually can be applied no longer, probably due to the superimposition of other reactions. It should be noted that the concentration of the species which determines the potential is that concentration which is in the electrolyte near to the electrode.

When the electrode reaction involves one of the constituents of the solution, which is usually the case in the cathodic reaction, the potential changes due to a change in the concentration at the interface and becomes dependent on the rate of diffusion of the constituent to the metal surface. For this reason the potential of metals such as iron, particularly in solutions containing oxygen, is very dependent on rates of stirring.

The rate of a reaction is determined by the activation energy of the reaction. When this is small the rate is usually high. Electrochemically the activation energy can be considered to manifest itself as overvoltage. On metals such as iron, where the overvoltage for hydrogen deposition is high, this has a marked effect on the potential, especially in air-free solutions. Impurities on the iron surface will often

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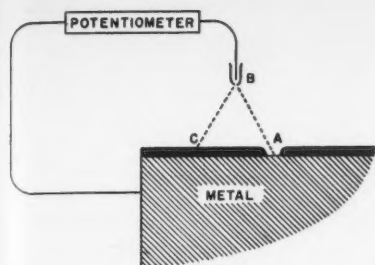


Figure 1—Schematic diagram of a potential measuring circuit showing anodic (A) and cathodic (C) areas and point of measurement (B) in solution.

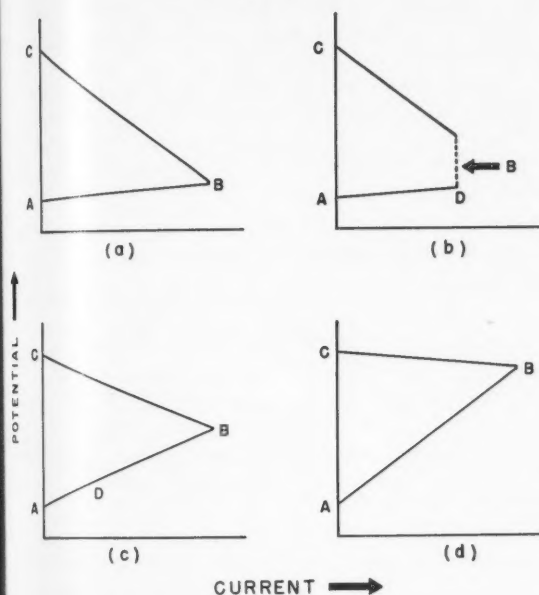


Figure 2—Types of polarization curves.

- High cathodic polarization and low resistance.
- High solution resistance. The measured potential is dependent on the position of the measuring electrode.
- Equivalent anodic and cathodic polarization.
- High anodic polarization.

tend to lower the overvoltage and alter both the polarization and effective potential. There may also be an activation energy and overvoltage associated with the removal of metal ions from the metal lattice to the solution which would contribute to anodic polarization.

The electrochemical corrosion reaction differs from the ordinary chemical reaction in that the cathodic and anodic reactions are interlocked and must balance each other, so that the rate, expressed in amperes, of the anodic reaction must be equal to the rate of the cathodic reaction. Thus a highly polarized cathodic reaction, such as the evolution of hydrogen on iron in air-free solutions, decreases the possible rate of the anodic reaction and hence the rate of corrosion. Although the total reaction rates are the same, the overall areas of the cathodes and anodes are different and therefore the current densities are different.

In any corroding system there is the possibility of

direct chemical reaction, as well as the electrochemical reactions. The most common example is the direct reaction of dissolved oxygen with the metal surface. This reaction will have no direct effect on the potential measurement but may have an indirect effect in that it changes the relative sizes of the cathodic and anodic areas and hence the current density and polarization.

When there are at least two electrode processes occurring on a metal surface, as in a corroding system, the value of the potential which is measured is somewhere in between the potentials of the working electrodes. Figure 1 is a diagram of a single anode surrounded by a cathode in a solution with a measuring half-cell connected to the metal.

If the probe electrode, such as an Ag/AgCl electrode, is inserted in the solution at Point B, the potential measured by the potentiometer is the difference between the potential of the probe electrode and the potential of the solution at Point B. This latter potential must be such that the potential drops from both C (the cathodes) and A (the anodes) give the same potential. (For iron the C area is usually an oxide film.) The value of the potential at B therefore is dependent on the resistance paths to B from A and C. The overall resistances of the electrolytic path can be roughly divided into three types, namely: the cathode film resistance, the anode film resistance and the solution path resistance, and,

$$\Sigma R = R_{cf} + R_{af} + R_s$$

Where  $R_s$  is an appreciable part of  $\Sigma R$  then the measured potential is very dependent on the position B of the probe electrode. Under this circumstance it is possible, by moving the probe electrode, to measure approximately the potentials at the cathodes and anodes and this has been done by a number of authors.<sup>4,5</sup> The fact that there are potential differences in the solution due to current flow has also been used to estimate the total current in a corrosion cell and to correlate this current with the total amount of corrosion.<sup>6</sup>

When  $R_s$  is small in comparison to  $\Sigma R$  the potential measurement is practically independent of the position B of the probe electrode. The value of the potential then depends upon the relative sizes of  $R_{cf}$  and  $R_{af}$ . When  $R_{cf}$  is large in comparison to  $R_{af}$  the measured potential will approach that of the anode and conversely when  $R_{af}$  is large in comparison to  $R_{cf}$  the measured potential will approach that of the cathode.

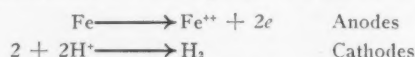
When the potentials of the anodes and cathodes are nearly equal in value, either due to the electrode reactions involved or polarization, the potential measured also will be fairly independent of the position of the electrode in the solution. These nearly equal potentials combined with any appreciable resistance will lead to a low current and low corrosion rate. The practical safety of galvanic couples from the corrosion point of view is often based on their potentials.<sup>7</sup>

Polarization curves are often used to illustrate how the potential is affected by the polarization of the anodes and cathodes. Examples of these are given

in Figure 2. A and C are the unpolarized anodic and cathodic potentials. When the resistance ( $\Sigma R$ ) between the anodes and cathodes is low, the potential is given by the intercept B of the anodic and cathodic polarization curves and if the corrosion is under cathodic control, as in (a) the potential read will be approximately that of the anodes. (The corrosion rate is said to be under cathodic control when the slope of the cathodic polarization curve is much steeper than the slope of the anodic polarization curve.) However, if there is appreciable resistance between the anodes and cathodes the potential read will be somewhere along a line such as D and will depend on the positioning of the measuring electrode. If this resistance is mainly electrolyte resistance ( $R_e$ ) it is possible, by correct positioning of a small probe electrode, to measure the polarized potentials of the anodes and cathodes. If a large part of this resistance is due to adherent films on the anodes and cathodes, the measured potential will be quite different from that of either the anode or cathode. These polarization curves are often quite helpful as another method of expressing results, but they can not usually explain the reasons for the results. Also a more useful polarization curve should be expressed in terms of current density and it is usually impossible to determine the real areas of the working anodes and cathodes on a corroding metal.

Measurements of potential-time curves have been most useful in helping to understand corroding systems. With some knowledge of the chemistry and geometry of the system the potential-time curve is very valuable in explaining many corrosion phenomena. Isolated electrode potential measurements also can be useful if there already exists previous knowledge concerning the system. Thus, in solutions which are borderline between corrosion and passivity a potential measurement will often determine whether the metal is active or passive. This type of measurement will not, of course, measure the rate of corrosion and without some knowledge of the system a potential measurement can be misleading. Thus Brown and Mears<sup>8</sup> have shown that in the presence of a good cathodic depolarizer such as ferric chloride in a sodium chloride solution, the potential of stainless steel does not change when corrosion starts. In the absence of a depolarizer of this type, Berwick and Evans<sup>9</sup> obtained a correlation between potential and activity or passivity with stainless steel.

In the absence of oxygen or other oxidizing agents the reactions of iron in aqueous solutions are:



The cathodic reaction is highly polarized (due to the large overvoltage for hydrogen evolution on iron) and the measured potential is almost solely dependent on the  $\text{Fe}^{++}$  concentration, which in turn is dependent on the  $\text{OH}^-$  concentration, of the solution. One should therefore expect that the potential will become more negative as the pH is increased and this is actually the case.<sup>10</sup> This results from a decrease in  $\text{Fe}^{++}$  concentration with an increase in  $\text{OH}^-$

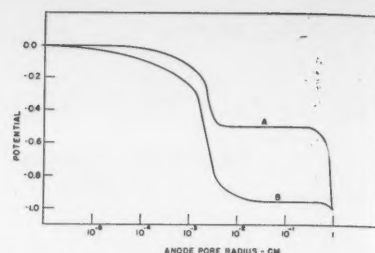
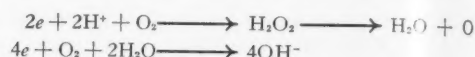


Figure 3—Variation of potential with anode pore radius. A—mixed polarization. B—high initial cathodic polarization.

concentration. Because of the high polarization of the cathodes, the rate of corrosion is low and decreases with increasing pH despite the fact that the potential is more "anodic."

In the presence of oxygen reaction probably remains the same, but the number of possible cathodic reactions increases and as a result the cathodes are depolarized. Among some of the possible reactions are:



The potential of the cathodes increases and the overall potential becomes slightly less negative, although the corrosion rate increases markedly. The oxygen also reacts with the  $\text{Fe}^{++}$  so that the corrosion product is no longer ferrous hydroxide but is a hydrated ferric oxide. This often leads to precipitation of corrosion product on the anodes, thus increasing the resistance at the anodes and may account for part of the increase in potential.

The addition of salts to the solution may have a number of effects. They will decrease the resistance of the solution ( $R_s$ ) and may also change the resistance of films or precipitates on the metal. This change of resistances will affect the potential measurement as well as the current and polarization. The addition of a salt such as sodium chloride will tend to reduce the resistance at the anodic areas and lower the potential slightly while increasing the rate of corrosion. However, in the presence of large amounts of sodium chloride, the corrosion rate begins to decrease, due to a decrease in the solubility of oxygen.

If the anion of the added salt forms an insoluble salt with the corroding metal ion, a precipitate will form over the anodic areas and the resistance ( $R_a$ ) will increase. This will tend to raise the measured potential and to decrease the rate of corrosion with time. In the presence of oxygen, with its ability to form oxide on the metal by direct reaction, the corrosion reaction may be stifled by the combined action of the spreading oxide film and precipitate in the pores of this oxide film. This will lead to both a stopping of corrosion and a passive potential. When the added ion is an oxidizing agent with respect to iron it will form an oxide film on the iron in the same manner as oxygen, and if conditions are right, will also lead to a passive potential and the cessation of corrosion. In both the latter two cases the passive potential is due to the high resistance in the pores

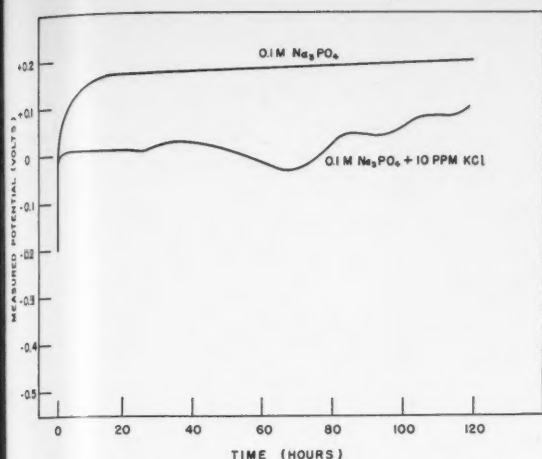


Figure 4—Effect of addition of KCl on "passive" potential.

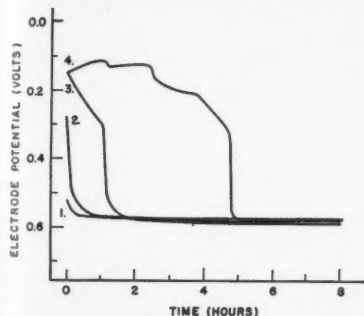


Figure 5—Effect of original surface condition on potential-time curves. 1) Film-free. 2) Freshly abraded with 3/0 emery. 3) As in 2) and exposed to dry air for 24 hours. 4) Abraded with 3/0 emery, dipped in 1:1 HCl for 30 seconds, washed, dried and exposed to dry air for 24 hours.

of the oxide film combined with the slowness of the corrosion reaction which leads to a low current density at the cathodes and reduced cathodic polarization. The passive potential is then the potential of the cathodic reaction polarized at a very low current density.

Assuming that the specific resistance of the pores is equal to the specific resistance of the solution, it is possible to calculate the potential which could be measured in the solution. This is shown in Table I.

In Figure 3 there is shown the type of graph one obtains from this. There is also shown in the B curve what happens when there is appreciable cathodic polarization—which is the case for iron. When the

TABLE I

Anode Pore Radius	Anode Resistance Total Resistance	Potential Measured
0.5 cm.	$0.77 \times 10^{-6}$	Between $E_a$ and $E_o$
0.1	$3.1 \times 10^{-4}$	Between $E_a$ and $E_o$
0.01	$3.1 \times 10^{-2}$	Between $E_a$ and $E_o$
0.001	$7.5 \times 10^{-1}$	Between -0.25 and 0
0.0001	$3.1 \times 10^2$	Between -0.03 and 0
0.00001	$3 \times 10^4$	Between -0.0003 and 0

Area of Specimen	1 Cm <sup>2</sup>
Anode Potential ( $E_a$ )	1.0
Cathode Potential ( $E_o$ )	0.0
Film	100 Å Thick

anodic areas become small, anodic polarization becomes a factor and the potential approaches the cathodic potential even more rapidly than the resistance calculation would indicate. This same type of curve can be drawn for the case where the corrosion is initially controlled by anodic polarization.

It is implicit in all the above argument that, for iron, the anodic reaction is always  $Fe \rightarrow Fe^{++} + 2e$  and that the anodic potential will be that of this polarized reaction. Although the reaction  $Fe \rightarrow Fe^{+++} + 3e$  probably can take place under conditions of impressed current, it is believed that it does not take place under conditions of natural corrosion. The direct reaction of oxygen with iron or the oxidation of ferrous ion in solution will form a trivalent compound, but the electrode reaction in all cases of natural corrosion is most probably  $Fe \rightarrow Fe^{++} + 2e$ . This differs from the views of Müller<sup>11</sup> and Hoar<sup>12</sup> who stated or implied that the depolarized cathodic reaction could polarize the anodic reaction to a potential where the  $Fe \rightarrow Fe^{+++} + 3e$  was possible. Although the measured potential in the case of passivity might indicate that this latter statement is true, considerations of resistance would indicate that the potential of the working anode is considerably smaller than the measured potential. The effect of resistance on the measurement of potentials has also been treated by Pearson<sup>13</sup> and Petrocelli.<sup>14</sup>

The above concepts are useful in interpreting time-potential data and help to explain the actual processes which are taking place. It is, of course, usually necessary to know other facts concerning the system. With iron in solutions with a pH above 4 the surface is at least partially covered with an oxide film and the anodic areas are holes or holidays in this oxide film. The cathodic areas are still covered by the film. When a piece of iron which has been exposed to air, and has on it the imperfectly protective air-formed oxide film, is immersed in a solution the initial potential is usually mid-way between the active and passive potentials. The change of the potential with time depends on the state of the initial oxide film and on the constituents of the solution. If an inhibitor is present the film is repaired, the anodic areas decrease in size, with a consequent increase in both anodic resistance and polarization, and the potential becomes passive. In Figure 4 there is shown the potential-time curves for freshly abraded iron in an oxygen-containing 0.1 M solution of tri-sodium phosphate.<sup>15</sup> One of the solutions contained 10 ppm of potassium chloride and it is seen that the potential in this solution is not as constant nor as "noble" as it is in the absence of chloride. This is probably due to the high diffusion rate of the chloride ion, which will decrease the resistance at the anodes and hence lower the potential.

The effect of surface treatment of iron in a weakly corroding solution, such as deaerated 0.1 M disodium phosphate containing 10 ppm potassium chloride is shown in Figure 5.<sup>15</sup> Here it can be seen that the more perfect the initial oxide film, the longer is the time required to reach an active potential.



The correspondence between weight-loss-time curves and potential-time curves are shown in Figure 6.<sup>15</sup> It can be seen that the potential and corrosion follow each other remarkably well. On the B curve the times to reach the passive potential and the cessation of corrosion are practically the same.

The effect on the potential of the availability of oxygen to the metal surface in the presence of varying amounts of inhibitor is shown in Figure 7.<sup>16</sup> It can be seen that at high inhibitor concentration there is very little effect but that at low inhibitor concentration the effect of stirring is very marked. There is a time lag between the cessation of stirring and the drop in potential which probably corresponds to the time required for the anodic areas to increase in size. Stirring also decreases cathodic polarization, but in the absence of an inhibitor will not lead to a "passive" potential.

The effect of inhibitor concentration on the final passive potential is shown in Figure 8.<sup>16</sup> It can be seen that the potential is higher when the inhibitor concentration is lower. This is probably related to the fact that the film grown in the more dilute inhibitor solution has smaller pores (and is more perfect) than the film which is grown rapidly in more concentrated inhibitor solutions. This is supported by the observation of Mayne and Pryor<sup>17</sup> who found that the  $\delta\text{Fe}_2\text{O}_3$  patterns on iron obtained with chromate solutions were better when the dilute solutions were used.

### Summary

The potentials of metals in aqueous solutions have been discussed in relation to the electrode reactions and the geometry and resistances of the system. It has been shown that in all cases the measured potential is a mixed polarized potential and that its value is dependent on the distribution of the resistances in the electrolyte path of the circuit. The passive potential is close to that of the only slightly polarized cathode potential and is due to the very high resistance in the pores of the protective film. The active potential is above the anodic potential and very often a slight increase in potential in the "passive" direction indicates an increase in corrosion rate. Examples of the potential of iron as affected by inhibitors, chloride ion and surface treatment show that these concepts are useful in explaining the potential measurements.

### References

1. O. Gatty and E. C. R. Spooner. *The Electrode Potential Behaviour of Corroding Metals in Aqueous Solutions*, Clarendon Press, Oxford, 1938.
2. U. R. Evans. *Metallic Corrosion, Passivity and Protection*, Edward Arnold & Company, London, 1946.
3. J. W. Shipley and I. R. McHaffie. *Can. Chem. Met.*, **8**, 5, 121 (1924).
4. R. H. Brown and R. B. Mears. *Trans. Electrochem. Soc.*, **74**, 495 (1938).
5. J. N. Agar. See Reference 2, p. 416.
6. U. R. Evans and T. P. Hoar. *Proc. Roy. Soc. (London)*, **A137**, 343 (1932).
7. F. L. LaQue. *Corrosion Handbook*, John Wiley & Son, 1948, p. 416.
8. R. H. Brown and R. B. Mears. *Trans. Faraday Soc.*, **35**, 467 (1939).
9. I. D. G. Berwick and U. R. Evans. *J. Applied Chem.*, **2**, 576 (1952).
10. M. J. Pryor and M. Cohen. *J. Electrochem. Soc.*, **100**, 203 (1953).
11. W. J. Müller. *Zeit. Elektrochem.*, **40**, 119 (1934); *Trans. Electrochem. Soc.*, **76**, 167 (1939).
12. T. P. Hoar. *Trans. Faraday Soc.*, **45**, 683 (1949).
13. J. M. Pearson. *Trans. Electrochem. Soc.*, **81**, 485 (1942).
14. J. V. Petrocelli and A. Phillips. *Trans. Electrochem. Soc.*, **85**, 257 (1944).
15. M. J. Pryor and M. Cohen. *J. Electrochem. Soc.*, **98**, 263 (1951).
16. M. Cohen. *Trans. Electrochem. Soc.*, **93**, 26 (1948).
17. J. E. O. Mayne and M. J. Pryor. *J. Chem. Soc.*, **1949**, 1831.

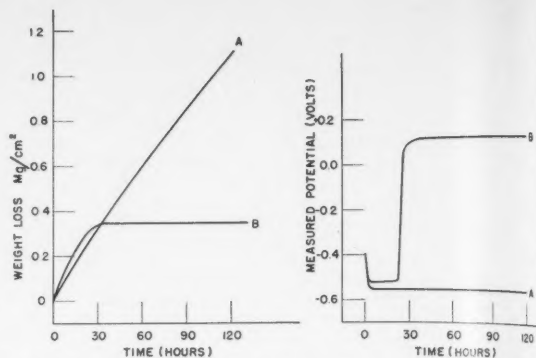


Figure 6—A comparison of weight loss-time and potential-time curves of iron in 0.1 M  $\text{PO}_4$  at pH 7. A—absence of oxygen. B—presence of oxygen.

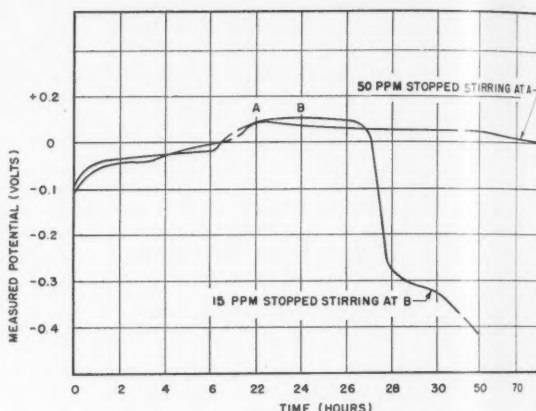


Figure 7—Effect of stirring on potential.

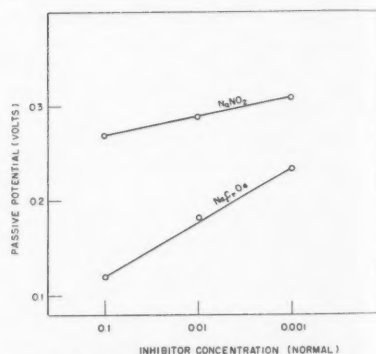


Figure 8—Effect of inhibitor concentration on passive potential at the end of 80 hours.

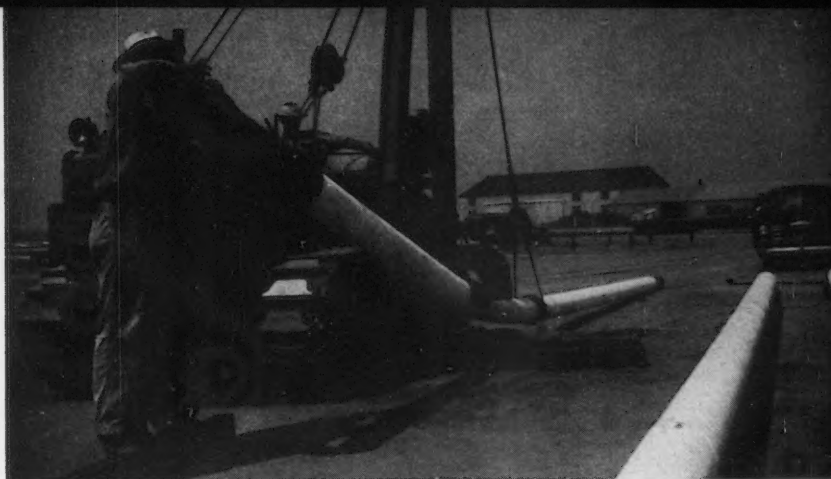


Figure 3-A—Method of field bending pipe with a side-boom tractor equipped with bending shoe.

## Field Tests of Exterior Coatings for a Pipe Line Conveying Fuel Oil Heated to 200 Degrees F\*

By E. R. STAUFFACHER\* and R. R. DAVIDSON\*\*

### Introduction

THE INCREASING use of high viscosity fuel oils in steam-electric generating plants has necessitated the practice of heating the oil for transmission between the source of supply and generating plant. Oil is heated and pumped into the pipe line at the source and reheated at intermediate pumping stations along the line. The pipe line under consideration was designed and installed for transmission of Bunker C oil of 20 degree API Gravity—175 SSF viscosity at 122 degrees F heated to 200 degrees between the source of supply at Santa Fe Springs, California and the Etiwanda steam-electric generating plant of the Southern California Edison Company's plant at Etiwanda, California. This pipe line is 41 miles in length, fabricated from 8-inch, Schedule 30 pipe and operates at a normal working pressure of 600 to 800 psi with three combined heating and pumping stations spaced at approximately 13.5 miles including the station at the sending end. The line traverses a combined level and hilly terrain in varying soils of sandy loam, decomposed granite and light clay.

The exterior protective coating to be applied to the line was of some concern because the quality and mechanical stability of underground pipe line coatings are put to a severe test when applied to hot-oil pipe lines. The stability of a bituminous material is generally dependent upon its softening point and although stability is greatly increased by using a high softening point material for hot lines, the quality may be impaired by an increase in brittleness at lower temperatures encountered during construc-

### Abstract

Field experiments were made to determine a suitable exterior protective coating for an oil transmission pipe line to handle oil heated to 200 degrees F. The 41-mile line was 8-inch Schedule No. 30 pipe operated at normal working pressure of 600 to 800 psi with three combined heating and pumping stations spaced at approximately 13.5 miles. It was designed to transmit fuel oil from the refineries to a steam-electric generating station.

To test stability, four different coatings were applied to 20-foot lengths of 8-inch pipes connected in series and buried in the soil. Oil heated to 200 degrees F then was circulated through the pipe for approximately two weeks. Provision was made to apply an external pressure of 10, 50 and 80 psi by the use of suitable rods and weights at three spots on each of the coatings. Depressions formed were measured carefully throughout the test to determine their rate and magnitude on each coating. Open ditch sections approximately 2 feet long for each coating were provided to permit observation of sag which might take place on any of the coatings. After the experimental hot oil circulation was completed the ditch was opened and the coatings examined for distortion and adherence and electrical resistance measurements were made at the depression points.

Additional 40-foot pipe lengths with each of the four different coatings then were subjected to cold bending by standard field equipment to a total angle of approximately 20 degrees and a minimum radius of approximately twenty pipe diameters (14 feet 5 inches). After each bend, the coatings were examined for cracks and given "holiday detector" tests to supplement visual examination.

Due to its ruggedness and freedom from distortion during the test it was decided to recommend a 1/2-inch thick asphalt mastic coating using a 250 degree F melting point asphalt for the hot-oil pipe line exterior coating.

tion. Accordingly, it was decided to make a field test of the stability of four different coatings under conditions simulating those encountered in transmitting heated oil. In addition, the ruggedness of the four coatings when subjected to cold (normal air temperature) bending was investigated.

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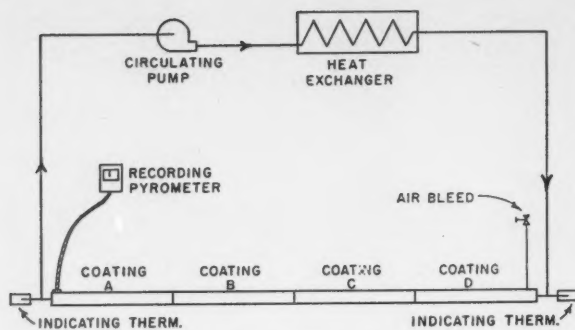


Figure 1—Schematic diagram of oil circulating equipment, instrumentation and sequence of test coatings.

TABLE I—Coating Designations and General Description

Coating	Type	Description*	Av. Total Thickness Inches
A	Asphalt Wrap	1 coat filled enamel 235-250° F. S.P. 1 glass-fiber wrap 1 coat filled enamel 240-260° F. S.P. 1 asphalt sat. rag felt wrap	0.250
B	Coal-Tar Wrap	1 coat 240° F. S.P.A.W.W.A base filled to 260° F. S.P. 1 glass-fiber wrap 1 coat—same as first enamel 1 coal-tar sat. asbestos felt wrap	0.250
C	Coal-Tar Wrap	1 coat enamel (special formula) 240-260° F. S.P. 1 glass-fiber wrap 1 coat—same as first enamel 1 coal-tar sat. asbestos felt wrap	0.156
D	Asphalt Mastic	1 coat seamless extrusion mastic Asphalt 250-265° F. S.P. 12-14% by wt. Mineral aggregate 87-85% by wt. Asbestos fiber 1% by wt.	0.500

\* In all cases pipe was cleaned and appropriate primer applied.

#### Preparation of Coatings

Two 40-foot lengths of 8-inch Schedule 30 steel pipe were coated with each of the four exterior pipe coatings. After all coatings were applied at coating plants selected by the manufacturers submitting specimens coated pipe then was delivered to the testing site. All enamels were applied hot and the wrappings were applied with a 1-inch lap under the usual plant conditions. The high melting point enamels required slightly more care in application, due to the higher temperatures involved, than is usually required in the application of the lower melting point enamels. The designations and general descriptions of the coatings are shown in Table I. All test specimens of pipe were properly cleaned and primed before coatings were applied.

#### Setup of Test—Hot Oil Circulation

When the coated pipes were delivered to the testing site one of each of the 40-foot lengths of pipe with the different coatings was set aside for the cold bending tests. Each of the remaining 40-foot lengths was cut into two 20-foot lengths, one length of each coated pipe being retained for examination and chipping of the coating to inspect adhesion. The four remaining 20-foot lengths, each with its different coating, were placed in a ditch and welded together in series for the hot oil circulation as shown in Figure 1. Measurements were made by outside calipers to check thickness of coatings including outside

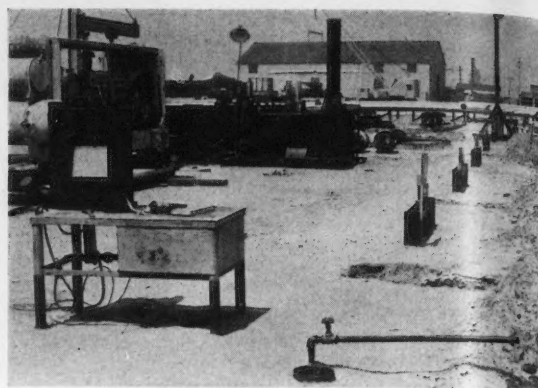


Figure 1-A—General view of hot oil circulation test setup.

wrap, where used and based on an outside diameter of 8½ inches for the bare pipe. These thickness measurements are included in Table I.

Connections were made to both ends of the composite 80-foot section (four 20-foot lengths) of the coated pipe to a gas-fuel heat exchanger for heating the oil and to a circulating pump. A dial-type indicating thermometer was mounted at each end of the pipe section and a recording pyrometer was mounted at the outgoing end in the heated oil stream where it left the pipe section. The coated pipe was placed in a ditch with 18 inches of cover except at four locations—one for each different coating where the pipes were left exposed for visual examination and checking for sagging during the test. These excavations exposed about two feet of pipe over the entire circumference for each type of coating.

The pipe was laid in sandy loam and, in order to simulate concentrated pressures due to rocks or lumps of heavy clay, provision was made to apply varying concentrated pressures by external means. To apply these pressures a fabricated steel frame approximately 5 feet long and 2 feet 10 inches high was welded at its base to each of the four sections of pipe. Three steel rods weighing 4½ lb., 22½ lb. and 36 lb. of lengths varying from approximately 3 feet to 3 feet 8 inches were used to apply 10 psi, 50 psi and 80 psi loads respectively. Three steel guide tubes 2 inches, 2⅜ inches, and 2⅞ inches OD were mounted vertically on the steel frame so that the lower ends had a clearance of ¼ inch above the coating. The rods were provided with pressed-on collars that provided concentric guiding and eliminated binding if the tubes were sprung. The ends of the rods were machined to a flat face and the lower end of each rod was turned down to ¾ inch diameter. Provision was made at the upper end of the concentric guide tubes to measure the relative distance between the top of the tubes and the top of the rods as the test proceeded. These measurements were made with a machinist's micrometer depth gauge. The frames were welded to the pipe at locations where the ditch was completely backfilled. At the lower end of the guide-pipes, where the ¼-inch clearance above the pipe coating was provided, a heavy paper collar was placed to prevent soil from getting between the end of the movable pressure rod and the pipe coating.



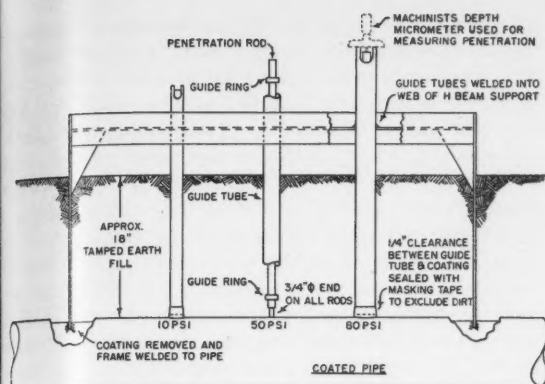


Figure 2—Installation of penetration rods and supporting framework.

Figure 2 shows the penetration equipment and the method of measuring the depth of the depressions as they developed.

### Operation of Test

After the pipe was laid, the measuring frames attached and the ditch backfilled except for the four 2-foot observation holes, circulation of the oil was started. Approximately 400 gallons of oil was used in the system and it required 12 hours to raise the temperature from 78 to 200 degrees F. No attempt was made to apply undue stress to the coating by rapid heating of the oil. The oil was circulated for a total period of 164.5 hours (6 days—20.5 hours). During this time the oil was kept at temperatures of approximately 200 degrees F for 116.5 hours, at 225 degrees F for 12.5 hours and between 200 and 225 degrees F for 3.0 hours. This totals 132 hours (5.5 days) for the period during which the heated oil was circulated. The remaining 32.5 hours were consumed in heating and cooling the oil.

Before beginning circulation of the heated oil and during the period of circulation measurements were made of the depressions as they developed. The machinist's micrometer depth gauge shown in Figure 2 was used throughout the test.

Four open sections of the ditch—one for each of the four different coatings, were provided to observe and measure any sag or deformation which might take place on the coatings. Open sections of the ditch were approximately 2 feet long and were excavated about 18 inches below the base of the pipe to provide sufficient space for careful examination of the coatings.

After the hot oil circulation period of the test was completed and the oil and pipe sections were cooled, the ditch was opened and each coating was examined for distortion and any apparent loss of adherence. At each of the twelve depression points—three for each coating, electrical resistance measurements were taken to determine the condition of the coating. The depression areas were nominally  $\frac{7}{8}$ -inch in diameter even though the ends of the depression rods were only  $\frac{3}{4}$ -inch in diameter. This increase of diameter was due to slight movement of the pipes during heating and cooling with a resultant slight distortion of the coating on the edges of the penetration rod areas.

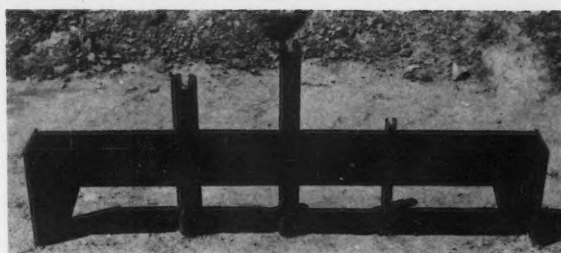


Figure 2-A—Exposed portion of penetration equipment during test.

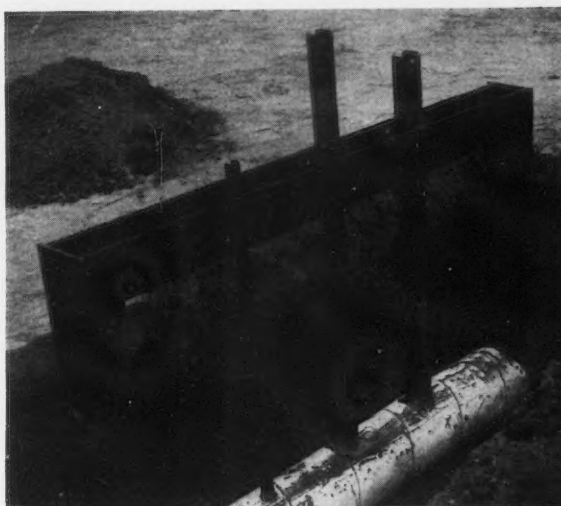


Figure 2-B—Excavation of pipe at penetration equipment showing attachment to pipe.

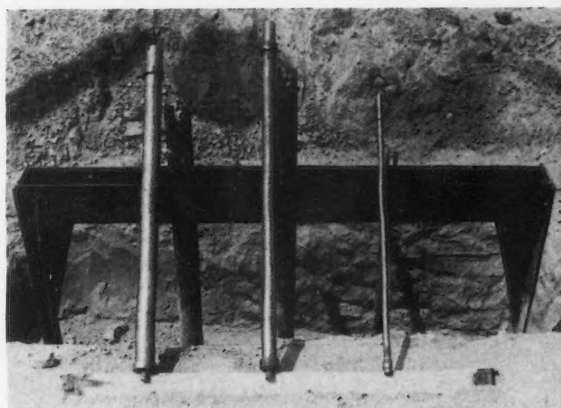


Figure 2-C—Dismantled penetration equipment showing penetration rods.

The electrical resistance of the coating was measured with a General Radio Co. Type 729-A Megohmmeter having an infinity rating of about 100,000 megohms. Each of the depressions was filled with a normal sodium chloride solution and allowed to soak for one hour. The resistivity of the coating remaining at the test points was determined by connecting one lead from the megohmmeter to the bare pipe and attaching the other lead to a brass electrode immersed in the salt solution. The actual resistance measurements

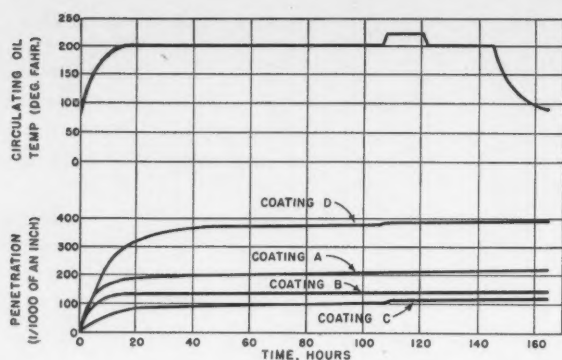


Figure 3—Comparison of circulating oil temperatures and penetration curves for 50 psi loading.

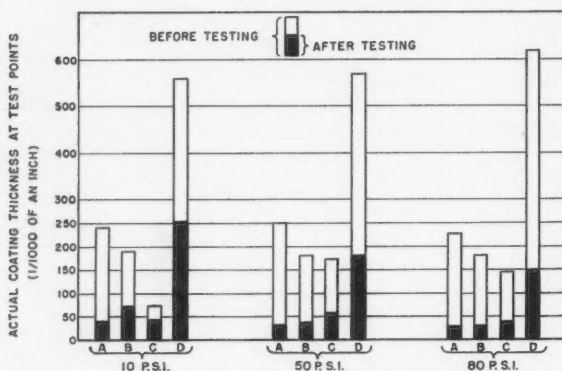


Figure 4—Graphic comparison by pressure groups of coating thicknesses before and after penetration tests.

were translated into ohms per square foot resistance of the coating remaining in the depressions in order to conform to the usual designation for the resistance of a pipe line coating.

#### Results of Test—Hot Oil Circulation

Results of the prolonged circulation of heated oil and the development of the depressions are shown in Figure 3 for 50 psi loading on each of the four coatings. Only one of the three loadings (10, 50 and 80 psi) is shown for the sake of clarity and is typical of the rate of depression for the three loadings. It will be noted that there was a high rate of depression taking place as the oil was being raised to 200 degrees F. After approximately 20 hours in the case of three of the coatings and 40 hours in the case of the fourth, the depressions developed very slowly. When the temperature of the oil was raised from 200 degrees F to 225 degrees F, two of the coatings showed a marked increase in the penetration for about one and one half hours but in general all coatings stabilized after the high initial penetration rates.

A graphic comparison by pressure groups of coating thicknesses before and after penetration tests of the four different coatings is shown in Figure 4. It can be seen that the initial thicknesses of the four coatings vary considerably, apparently due to irregularities encountered in application of protective coatings. Also in some cases the location of the penetration rods either over or between laps of the

outer wrap may account for the variation. In general the thickness of the coating remaining decreased as the loading increased, as would be expected, but in the case of Coating C, this progression did not hold because of the abnormally thin coating under the 10 psi loading. The penetration equipment was installed without consideration of abnormalities in the various coatings.

After excavation of the pipe the thickness of the coating remaining at the penetration points and the respective electrical resistances of the remaining coating were measured and are shown in Table II for each of the four coatings. The resistivities, in ohms per square foot, vary considerably and are not consistent as regards the pressures applied at the various locations. However the results give a rough indication of the relative strengths of the coatings supplied and under the conditions of the test. Probably a considerably greater number of tests would have to be made to establish truer average results.

During progress of the test, coatings in the 2 foot open sections of the ditch were examined for sagging, distortion, or change of exterior dimensions. Checks with calipers showed that the exterior diameters had not changed within the limits of  $\frac{1}{32}$  inch and that no sagging had taken place in these short unsupported sections.

After the heated-oil circulating tests were completed and the resistivities measured at the locations where the pressures had been applied, the coating was removed at these spots for examination. As would be expected, thickness of the glass-fiber reinforced enamel coatings became progressively less as the applied pressures became greater. The total material remaining varied from 0.027-inch to 0.072-inch and in some cases this thickness was composed almost entirely of glass fiber and outer felt. As has been shown previously in Figure 4, the thickness of the asphalt mastic coating remaining varied from  $\frac{1}{4}$ -inch to approximately  $\frac{5}{32}$ -inch.

The portion of each of the four pipe sections which had been buried in the ground and subjected to the sustained temperature was then examined. Visual inspection of the outer surface and chipping off of portions of the coating was resorted to as a means of determining if any distortion or sagging had developed. Observations can be summarized as follows:

**Coating A—Asphalt wrap.** Slight deformation showing soil and clod penetration of portions of the bottom not exceeding  $\frac{1}{8}$ -inch. Enamel does not chip easily and therefore is resistant to impact damage. Under the chipped portions, found good bond between enamel and pipe, good bond between

TABLE II—Coating Penetration Results and Resistivities

Coat- ing	Thickness of Coating Remaining at Penetration Points, Inches			Resistivity of Coating Remaining at Penetration Points, ohms/Ft <sup>2</sup>		
	10 PSI	50 PSI	80 PSI	10 PSI	50 PSI	80 PSI
A	0.041	0.032	0.027	3,330,000	250	1,500
B	0.072	0.037	0.031	2,500	0	5,000
C	0.046	0.039	0.040	17,000	38,000	417,000,000
D	0.254	0.180	0.151	417,000,000	25,000	

first and second coats of enamel, glass fiber thoroughly saturated and good bond between outer enamel and felt wrapper.

**Coating B**—Coal-tar wrap. Slight sagging and deformation of portions of the bottom showing soil and clod penetration not exceeding  $\frac{1}{8}$ -inch. Enamel does not chip easily and therefore is resistant to impact damage. Good bonding throughout except at a few spots between enamel and outer felt where voids had developed.

**Coating C**—Coal-tar wrap. No sagging and very little distortion of coating. Coating chips easily and is therefore subject to impact damage. Under chipped portions found good bond between enamel and pipe, poor bond between first and second coats of enamel and poor saturation of glass fiber. Some voids noted between outer wrap and enamel.

**Coating D**—Asphalt mastic. No apparent sagging. Slight distortion on portions of the bottom showing soil and clod penetration not exceeding  $\frac{1}{8}$ -inch. Difficult to chip off coating which therefore is resistant to impact damage. Good bond to pipe surface.

### Cold Bending Tests

A series of cold bending tests were made to determine the behavior of the four different pipe coatings under field bending conditions at atmospheric temperatures. The four 40-foot pipe lengths previously set aside for bending tests were then subjected to bending by a side-boom tractor equipped with a 16-inch long, straight-type bending shoe. Bends were made in increments, ranging from 2 degrees to  $3\frac{1}{2}$  degrees, during that part of the day when the air temperature was between 70 and 80 degrees F and no supplemental heat was used. The  $3\frac{1}{2}$ -degree increment of bending approximated a bending radius of 20 pipe diameters which was considered a minimum radius for field bends. All bends were checked, by both visual examination and holiday detector tests. Results are shown in Table III. It will be noted that at 2-degree bending increments, all but one coating bent without damage while at  $3\frac{1}{2}$  degrees only one coating bent successfully. On the basis of these tests, it is apparent that field bending, in three out of the four cases, did not damage the coating when the bending increment was not in excess of 2 degrees

TABLE III—Results of Cold\* Bending Against A Straight Shoe  
In  $\frac{1}{2}^\circ$  Increments from  $2^\circ$  Through  $3\frac{1}{2}^\circ$

Coat- ing	Bending Results by Increments				Extent of Damage and Reparability
	$2^\circ$	$2\frac{1}{2}^\circ$	$3^\circ$	$3\frac{1}{2}^\circ$	
A	ND	ND	ND	D	Single heavy crack—partial loss of bond to pipe—reparable by removing small section of coating and patching.
B	ND	ND	ND	ND	No cracking or other damage occurred to coating—no repairs required.
C	D	D	D	D	Multiple heavy cracks—partial loss of bond to pipe—reparable only by re-wrapping bend section.
D	ND	D	D	D	Multiple hairline cracks—bond to pipe intact—reparable by heating and troweling.

D—Damaged.

ND—Not damaged.

\* All bends were made during ambient temperature range of  $70^\circ$ - $80^\circ$  Fahr., and without supplemental heat.

at air temperatures of 70 to 80 degrees F. In the case of Coating C, supplemental heating apparently would be required for field bending.

### Conclusions

Upon completion of the described tests, results were evaluated and the decision made to recommend the use of Coating D, an asphalt mastic coating.

Factors influencing this choice were: A clearly superior performance under penetration tests with high resulting resistivities; satisfactory bending properties particularly at 2 degree increments or less; ease of repair if bending damage is incurred and high resistance to impact damage at temperatures prevailing during the test period. By way of comparison, coating C, ranking second in penetration results and resistivities, shows poor bending properties and a low resistance to impact damage. Coatings A and B, while showing excellent bending properties and a high resistance to impact damage, were the least satisfactory of the four coatings from the standpoint of penetration results and resistivities. Had time permitted, a duplication of the penetration tests would have resulted in more accurate average results but it was felt by all concerned that results obtained fulfilled the requirements and were indicative of results that would be obtained by a multiplicity of tests.

Authors express their thanks to manufacturers and the applicators of the coatings tested. Their cooperation and advice in planning the tests and the use of their yard facilities are greatly appreciated.





# Discussions

## Magnetic Amplifier Controls for Rectifier Protecting Underground Metallic Structures Cathodically. By Oliver Henderson. *Corrosion*, Vol. 9, No. 7, 216-220 (1953) July.

Discussion by H. G. Sheard, Seaford, N. Y.:

In the abstract and several places in this paper the terminology "forced drainage" is used. While such terminology may be acceptable for some in designating one method of protecting structures exposed to electrolysis, it is a definite departure from sound engineering language. The use of a rectifier on underground structures (in the method described) exposed to electrolysis merely changes the net resultant current flow and causes the structure to receive current instead of discharge it. In other words, it is picking up more rectifier current than it is discharging stray current. This is an application of the Superposition Theorem,\* and is in no sense "forced drainage," or even drainage. I realize that this term, "forced drainage" has been used by many consulting engineers in the past. However, it should be abandoned, for without good usage of engineering terms, misunderstanding by readers will doubtless result and consequently retard advancement of sound thinking in the application of cathodic protection.

\* Superposition Theorem.—In any network containing generators and linear resistances, the current flowing at any point, due to the simultaneous action of a number of sources of emf distributed throughout the circuit, is equal to the sum of the currents at this point which would exist if each source were considered separately, all other generators being replaced at the time by their internal resistances.

Reply by Oliver Henderson:

Mr. Sheard's point is well taken and is technically correct. In telephone engineering we have many terminologies which may be peculiar to the industry. For example, in our Bell System Practices, "forced drainage" is recommended for use "where no negative bus is available and current is forced from the cable sheath to a specially constructed current carrying ground." It is to be noted also that "forced drainage" is so described on page 936 of Dr. Uhlig's Corrosion Handbook.

## Corrosion by Aqueous Solutions at Elevated Temperatures and Pressures. By F. H. Beck and M. G. Fontana. *CORROSION*, Vol. 9, No. 8, 287-293 (1953) Aug.

Discussion by William G. Ashbaugh, Galveston, Texas:

The authors are to be complimented on the presentation of this interesting data on corrosion at elevated

temperatures and pressures. As they have indicated so well, it is often erroneous to extrapolate data obtained at lower conditions of temperature and pressure.

When working with solutions at high temperatures and pressures, the role of the pressuring gas is often quite important and may strongly influence the effect of the medium. I should like to ask the order of magnitude of the pressures obtained at the various temperatures and whether these were the equilibrium pressures of the media or were artificially induced from an external source?

We have noted that the effect of dissolved oxygen not only is extremely important but also that its removal from certain media is not as simple as one might think. Specifically, the sparging of an inert gas such as nitrogen does not insure anaerobic conditions within the solution. Have the authors run tests in air-free as compared with air-saturated solutions? If not, is this on the agenda?

Reply by F. H. Beck:

With regard to the discussion by Mr. Ashbaugh the authors would again like to emphasize the danger in extrapolating corrosion data obtained at low temperatures and pressures to applications at elevated temperatures and pressures.

The pressures used for these tests were in most cases the equilibrium pressures of the media at the indicated test temperatures. In some instances external pressures of from 100 to 700 psig were applied for the nitric tests. The results are discussed on page 290 of the paper. There was no appreciable change when the oxygen pressure was varied in the range indicated above. We believe that pressure in itself has little effect when compared to the effect of temperature.

Although we have no data at present for tests conducted in air-free acid we do intend to incorporate such tests in the present program.

Question by Wm. E. Baker, Standard Oil Co. of Ohio, Cleveland:

Did you find evidence of erratic corrosion rates or of pitting in your testing of alloys in phosphoric acid? This has been a problem in commercial units using copper pyrophosphate catalyst.

Reply by F. H. Beck:

The authors believe that the inhibiting effect of copper in phosphoric acid results from a complex copper ion which acts as an anodic inhibitor. If such is the case it might well be expected that erratic behavior and pitting would be encountered if insufficient inhibitor were present. The concentration of the acid, concentration of the copper and temperature

fluctuations would be factors. There were no indications of pitting observed in our tests, but this may be because relatively short exposure times were used.

**Questions by Werner O. Tundermann, Colgate-Palmolive-Peet Co., Jersey City, N. J.:**

Were any other metallic salts tried as inhibitors for the phosphoric acid tests on cast stainless steels?

Do you believe that the effectiveness of  $\text{Cu PO}_4$  as inhibitor for the above test study was due to the oxidizing characteristics of the copper ion?

**Reply by F. H. Beck:**

The oxidizing characteristics of the copper ion are important in its behavior and undoubtedly play an important part in the mechanism of inhibition. No attempt was made to try other metallic salts as inhibitors for the phosphoric acid tests.

**Discussion by John W. Weis, Pasadena, Texas:**

In making tests, were there any indications that the corrosion rates decreased as temperatures were increased well above the boiling point of the aqueous solutions?

In one of our operations we have some indications that an aqueous ammonia solution into which other chemicals are introduced has the property of being extremely corrosive through a temperature range well above the boiling point of the solution. At temperatures above or below this critical range corrosion is negligible.

**Reply by F. H. Beck:**

The authors have not observed any examples of corrosion in their work such as encountered by Mr. Weis. At temperatures at and below the boiling point we have noted some trends of this kind.

**Discussion by Robert F. Hausman, General Electric Aircraft Nuclear Propulsion Project, Cincinnati, Ohio:**

Do the authors intend to make tests to obtain data on the corrosion affects caused by the heavy metal halides and boric acid solutions on the various metals used?

The questions directed to the authors of Paper No. 15 were prompted by the fact that corrosion and chemical literature contains very little information on the action of the semi-heavy and heavy metal halides (iodine and bromine) on the metals discussed in the paper. If one considers the semi-heavy metals as starting with element 38, then a large group of commercially important halide compounds must be taken into account corrosion-wise. The majority of these compounds could be processed or handled in containers fabricated of the metals listed in the paper if the range and extent of the corresponding corrosion processes were known.

One finds, also very little information in the literature on the action of boric acid solutions on the stainless and very high alloy materials. In particular

data are lacking on corrosion rate vs. temperatures up to and including the solution boiling point.

**Reply by F. H. Beck:**

We do not intend to obtain corrosion data on semi-heavy and heavy metal halides in the present program. However, these corrosives may be considered in the future.

**Corrosion of Casing in Oil and Gas Wells. By Jack L. Battle. CORROSION, Vol. 9, No. 9, 313-320 (1953) Sept.**

**Discussion by Jack P. Barrett, Stanolind Oil & Gas Co., Tulsa, Okla.:**

Results of 8-10 months' laboratory tests on a simulated well annulus the isolated, scattered deep pitting observed in the field was obtained in the absences of  $\text{CO}_2$ , mill scale and  $\text{O}_2$ . Atmosphere was prepurified oxygen free nitrogen W/300 ppm  $\text{H}_2\text{S}$ . Total pressure on system was 5 psig.

A 3½-foot section of 3-inch pipe with arrangement for condensing moisture at the top and heating water at the bottom was used as a test cell. The inside of the pipe was cleaned of mill scale and foreign material prior to test.

Approximately 500 cc of water was introduced into the cell and freed of air by sweeping with air-free nitrogen. After deaeration a mixture of air-free nitrogen containing 400 ppm of hydrogen sulfide was bubbled through the water until the cell was pressurized to 10 psig. This gas was changed daily except on weekends throughout the test.

At the end of nine months' exposure, the cell was disassembled and cut longitudinally to allow close inspection of all interior surfaces.

Inspection revealed that general isolated pitting had developed. Pits were deep, irregular and of the jagged nature as found on casing recovered from sour wells in West Texas.

It was concluded that the interior casing corrosion noted in sour wells could occur in the absence of  $\text{CO}_2$  and high pressures. Further it was shown that irregular jagged pitting can occur in an  $\text{H}_2\text{S}$ -water system where no  $\text{CO}_2$  is present.

**Some Notes on the Oxidation-Resistance of Boron-Containing Chromium-Nickel-Cobalt-Iron Alloys. By W. O. Binder and E. D. Weisert. CORROSION, Vol. 9, No. 9, 329-332 (1953) Sept.**

**Question by E. N. Skinner, The International Nickel Co., Inc., New York, N. Y.:**

In the iron-base alloys containing boron, were there any indications that the oxide formed may have been molten at the testing temperature of 2012 degrees F as would suggest the formation of a low melting eutectic between boron-iron oxides?

**Reply by E. D. Weisert:**

The method used to identify the various scales was

not sufficiently sensitive to detect the small amounts of boron-bearing constituents. The glassy appearance of some of the oxides formed on alloys containing considerable amounts of boron, suggests the possibility of a partially molten state at the 2012 degree F testing temperature. The glassy appearance, however, was not correlated to the major elements in these complex alloys.

**Question by M. A. Scheil, A. O. Smith Corp., Milwaukee, Wis.:**

How is boron used in stainless steels, to what extent is it used and what properties are enhanced by its addition?

**Reply by W. O. Binder:**

Boron has been utilized together with special heat-treatments to produce precipitation hardening of the matrix of 18-8 steel.<sup>1</sup> Very small additions of boron, particularly in conjunction with titanium, have been employed to increase the high-temperature properties of 4 to 6 percent chromium and 18-8 steels.<sup>2</sup> However, the latter developments have not been commercialized. The effect of small additions of boron in the high-temperature properties of austenitic chromium-nickel and chromium-nickel-cobalt alloys, containing molybdenum, tungsten, titanium and columbian has been extensively investigated by the Metals Research Laboratories of the Union Carbide and Carbon Corporation. This work led to the development of Haynes No. 88 alloy containing, nominally 12% chromium, 15% nickel, 2.25% molybdenum, 0.5% titanium, 0.5% tungsten, 0.01 to 0.1% boron, 0.08% carbon and the balance iron, which is currently being investigated for use in jet motors as rotor and bolting material. The alloy exhibits optimum strength in the hot cold-worked condition. Its service temperature is limited to about 1500 degrees F.

1. H. Bennek and P. Schafmeister. *Archiv. für das Eisenhüttenwesen*, 5, 615 (1931-32).

2. G. F. Comstock. *Metal Progress*, 56, 67 (1949).

**Cable System Design for Cathodic Protection Rectifiers. By Ray M. Wainwright, CORROSION, Vol. 9, No. 9, 325-328 (1953) Sept.**

**Question by William Dudley, Lake Jackson, Texas:**

Do your figures include any labor costs?

**Remarks by S. P. Ewing, Carter Oil Company, Tulsa, Okla.:**

In the discussion of this paper someone said he thought resistance of the ground bed, its distance from the line, the voltage of the rectifier and perhaps other factors entered into the determination of the proper size of wire to use. My remark was in answer to this question.

The answer is that the economical size of wire depends only on power and copper (or aluminum) costs. This is an essential point in the author's paper which I think is correct.

**Reply by Ray M. Wainwright:**

Dr. Ewing's reply to Mr. Dudley's question is quite correct. Labor costs would enter into a selection of the optimum cable size only if, say, the labor of installing the cable varied materially with the cross-section. While such cost variations might be possible with extreme changes in cross-section, the cable size is not affected in most practical situations.

In the selection of the optimum size the length of the cable is also immaterial. For example, we might set up the following relation for the equivalent uniform annual cost of neoprene-covered copper cable (1953 prices):

$$T = \frac{94.6 I^2 P L}{E A} + 0.15 L (0.03 + 2 \times 10^{-6} A + 3.08 \times 10^{-6} A X)$$

Here, T is the total cost in dollars per year on an annual basis

I is the cable current in amperes

P is the power cost in cents per kwhr.

E is the rectifier efficiency in percent

L is the length of the cable in feet

A is the area of the cable in circular mills

X is the base cost of copper in dollars per pound

If the above expression is differentiated and set equal to zero, an expression for A may be derived as follows:

$$A = 25,200 I \sqrt{\frac{P}{E (3.08 X + 2)}} \quad \text{circular mills}$$

This is the optimum cable size, and the length has disappeared from the expression in the differentiation process.

Other relationships may be worked out for other types of cable; however, this method does not show the flatness of the total amount cost curve as does the tabular method given in the article.



# Topic of the Month

## Visual Identification of Line Pipe

By HANS SCHMOLDT\*

VERY OFTEN during the course of his work it would be interesting or relevant for the engineer in the field to be able to identify specific kinds of pipe as to their method of manufacture. While it would require a complete laboratory examination to positively identify a specimen of pipe as to its specific API or ASTM specification, this brief report points out the characteristics of the various kinds of line pipe, so that they may be readily identified by visual examination when mill stenciling or other identification has been lost. A more complete study of pipe identification should include an understanding of the various steps of mill fabrication and a knowledge of a few simple and basic metallurgical tests which can be performed in the field. This discussion is not concerned with qualities or deficiencies of various kinds of pipe, nor their proper selection for field or plant use.

Line pipe generally can be classified into five groups related to method of manufacture. While mills attempt to produce the ultimate in uniformity and quality under a given specification, some processes of manufacture are more efficient than others and each kind of pipe produced has its proper field application. The five common pipe fabricating processes produce pipe which can be classified as follows: Seamless, electric resistance welded, electric fusion welded, lap welded and butt welded. In general, it can be said that while all imperfections are not injurious, pipe can be identified most easily through defects occurring during fabrication.

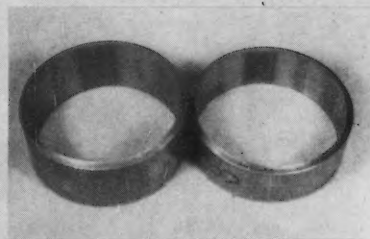
**Seamless**, as the class name implies, has no welded seam, but is produced by spinning and pushing a heated billet over a stationary piercing mandrel. By this process it is theoretically possible to manufacture a tube of uniform wall thickness, roundness and surface finish. However, one imperfection or a combination of slight imperfections produced into the pipe during fabrication serve positively to identify seamless pipe. Longitudinal spiraling internal mandrel scores in varying de-



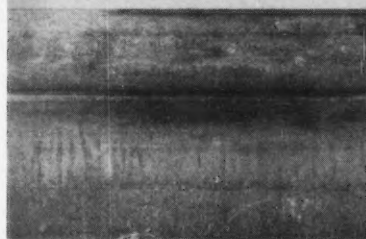
Seamless Pipe



Electric Resistance Welded Pipe (Flash)



Electric Resistance Welded Pipe (Continuous)



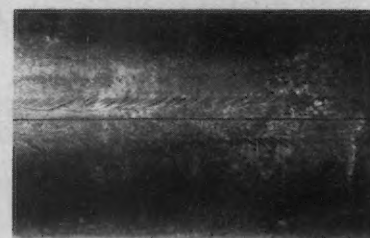
Electric Fusion Welded Pipe



Lap Welded Pipe



Butt Welded Pipe (Furnace)



Butt Welded Pipe (Continuous)

grees of depth and quantity are found. Another defect appears as spiraling folds, called "seams," which can be found on either surface for any length along a joint of pipe. A third characteristic of seamless pipe may be nonuniform wall thickness which results when the inside diameter is not concentric with the outside diameter. The thick portion of the wall will always be diametrically opposite the thin portion. Identifying characteristics:

1. Absence of a welded seam.
2. Longitudinal spiraling internal mandrel scores.
3. Spiraling internal or external folds (seams).
5. Eccentricity of ID to OD.

**Electric Resistance Welded Pipe** is cold formed from long lengths of hot rolled sheet, called skelp and then welded under pressure by heat from electric resistance without the addition of a filler metal. Two types come under this classification, each having its own characteristics. One type of resistance welded pipe currently made by one mill is formed into a tube in progressive pressing operations and welded instantane-

ously by a flash welding process. The principal identifying characteristic of this product is in the resulting upset weld. After welding, the flash is machined, leaving a keyed upset  $\frac{1}{32}$ -inch to  $\frac{1}{16}$ -inch high by  $\frac{1}{4}$ -inch to  $\frac{1}{2}$ -inch wide on both internal and external surfaces. Identifying characteristics:

1. Uniform wall thickness.
2. Smooth internal and external surfaces.
3. Flat key upset on both weld surfaces.

The second type of resistance welded pipe is formed on a series of forming rolls and electric resistance welded under stationary rolling electrodes as the pipe moves down the mill. The weld flash thus produced is completely trimmed off on both surfaces while still hot in an attempt to produce contoured surfaces flush with the contour of the pipe wall. Several irregularities are to be found in the weld zone to distinguish this type of manufacture. When new, the weld zone shows a characteristic metallic blue

(Continued on Page 2)

\*Huddleston Engineering Co., Bartlesville, Okla.

## Visual Identification—

(Continued from Page 1)

color where it has been heated. A worn electrode can cause a path of slight feathered electrode burns in the metal along both sides of the weld. Also, the internal flash trimmer can not be controlled as easily as the external trimmer and may leave either a slight upset band at the weld, or gouge a shallow undercut at the internal surface of the weld.

Identifying characteristics:

1. Uniform wall thickness.
2. Smooth internal and external surfaces.
3. Slight upset or undercutting at internal weld surface.

4. Electrode feather burns along external weld zone.

**Electric Fusion Welded Pipe.** While there are several types in this classification, all are electric welded with the addition of a filler metal. The weld can be made manually, the practice at small shops, or it can be made continuously with automatic equipment. The tube may be formed with a longitudinal weld seam, or it may be formed spirally. All types exhibit the typical weld bead of filler metal.

Identifying characteristics:

1. Uniform wall thickness.
2. Smooth internal and external surfaces.
3. Prominent fusion weld bead present.

**Lap Welded Pipe** is made by heating the entire skelp and then forcing it over a mandrel with a pair of rolls embossed with a herringbone or knurled pattern. The pressure of the welding rolls completes a lap weld and also impresses a most distinctive herringbone or knurled pattern into the external surfaces of the pipe. Longitudinal scratches caused by the mandrel often can be found on internal surfaces and the lapped edge of the weld often can be seen on either surface as an irregular line, especially after a period of use under corrosive attack.

Identifying characteristics:

1. Prominent external herringbone or knurled pattern.
2. Internal longitudinal scratches.
3. Lapweld sometimes visible as irregular line on either surface.

**Butt Welded Pipe** has been made in sizes not exceeding 4½ inches OD by two different processes, loosely called "furnace welded" and "continuous welded." In furnace welded pipe, skelp with square cut or slightly beveled edges is heated to welding temperature in a furnace and then drawn through a funnel shaped die or through welding rolls into tubular form with sufficient edge pressure to make a welded seam. Continuous welded pipe is the product of a more modern method of butt welding in that the skelp is drawn through a furnace from endless coils, the end of one coil being machine flash welded to the leading end of a new coil. The pipes produced by both methods are difficult to distinguish one from the other and either can be confused easily with seamless unless carefully inspected. Characteristic defects are few and not very pronounced when they do occur. Both types are smooth internally and externally with occasional external longitudinal scratches or feathered scratches adjacent to the weld. The straight well usually can be seen down the length of the pipe on either surface varying from an almost invisible hairline to a prominent V-shaped notch.

Identifying characteristics:

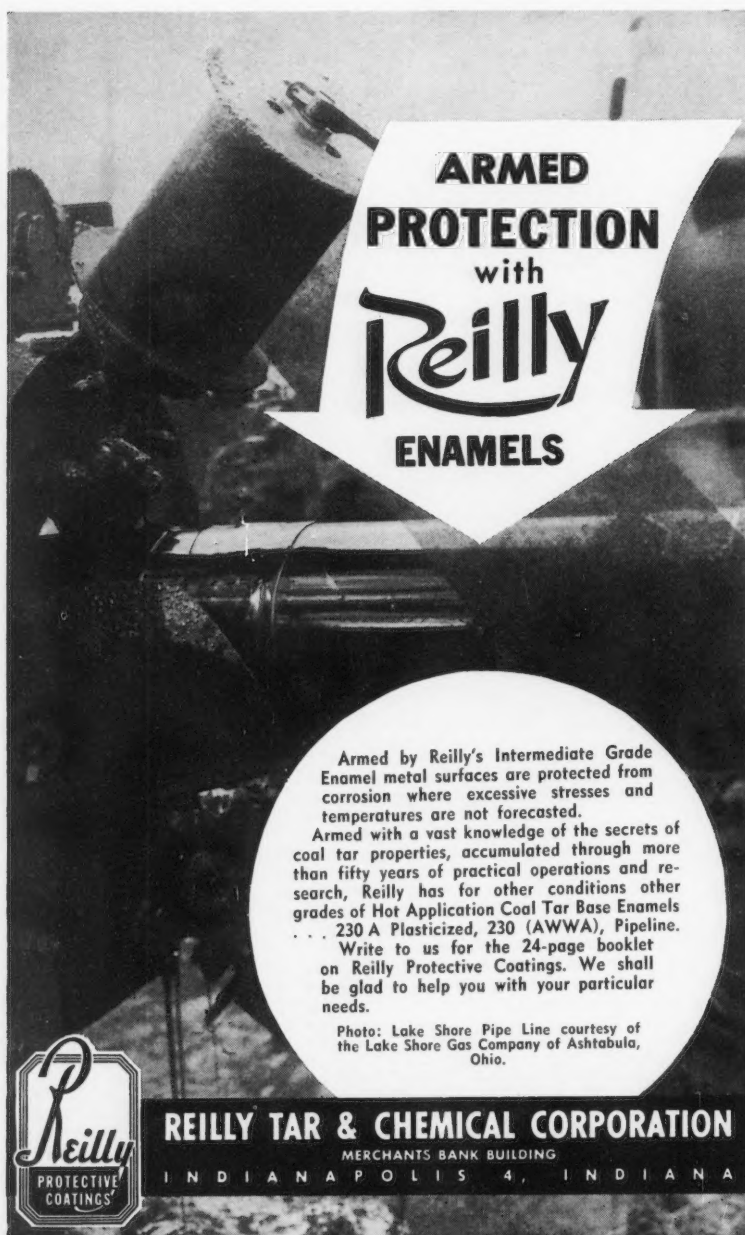
1. Smooth internal and external surfaces.
2. Longitudinal or feathered scratches adjacent to external weld.
3. Visible straight line weld internally or externally.

## Activated Bauxite Used In Adsorption Bed

Activated granular bauxite was used successfully as an adsorption bed to remove vaporized diethylene glycol and monoethanolamine from natural gas. The two chemicals, added to the gas to combine with and remove water and acids which caused corrosion and clogging of pipes, themselves vaporized in small volume into the gas. They then condensed in the pipeline and caused plugging.

The corrosion problem was successfully solved by a group under Dr. Thomas D. Nevens, associate research engineer in the Denver Research Institute's Division of Chemistry and Chemical Engineering. This work was reported in the institute's quarterly periodical, "Progress in Research," Vol. 1, No. 2.

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Photo: Lake Shore Pipe Line courtesy of the Lake Shore Gas Company of Ashtabula, Ohio.

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# NACE News

## Montreal, Portland, Ore. Sections Are Approved

### Philadelphia Section, ASTM Meeting Held

Philadelphia Section of NACE was scheduled to hold a joint meeting with the Philadelphia District, American Society for Testing Materials on September 18 in Philadelphia. This was the first joint meeting of these organizations.

C. L. Bulow, Corrosion Metallurgist, Bridgeport Brass Co., was the speaker for the technical portion of the meeting on copper and copper alloys. Mr. Bulow discussed copper and copper alloys from the standpoint of corrosion resistance, physical and mechanical properties and fabrication properties with emphasis being placed on the corrosion resistance of these materials under a variety of conditions. Influence of factors such as alloy composition, corrosive media, temperature, stress, corrosion inhibitors, cleanliness, etc., were shown.

Mr. Bulow, in addition to his activities on ASTM Committee B-3 and NACE Technical Practices Committee No. 5, is a member of ACS, Electrochemical Society, API and Institute of Metals.

A panel discussion moderated by Bob Pierce is scheduled for the October 23 meeting of Pittsburgh Section. Fields to be covered include cathodic protection, protective coatings, metals and alloys, general chemical plant corrosion. Names of panel members will be revealed later.

### Pending Short Courses On Corrosion Are Listed

Short courses on corrosion, being given with the cooperation of NACE have been announced as follows:

October 12-16, University of Illinois, Urbana. Full program reported in Corrosion, July, Page 13.

October or November, Shreveport Section. Annual corrosion short course.

November 16-19, University of California at Los Angeles. Full program given in Corrosion, August, Page 5.

December 1-4, University of Oklahoma, Norman. Seminar on corrosion.

February 8-9, 1954, University of California, Berkeley. Conference on Marine Corrosion.

February, 1954, Washington State College, Pullman.

March 24-26, 1954, University of Wisconsin, Madison.

Reprints of material published in Corrosion are usually made only on order. Tentative prices may be obtained from Corrosion, 1061 M & M Bldg., Houston 2, Texas.

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### NACE MEETINGS CALENDAR

- Oct.**  
20—Baltimore Section.  
7—Southern New England Section.
- Regional Meetings**
- Oct.**  
7—Northeast Region, New Haven, Conn. Hotel Taft.  
7-9—South Central Region, Mayo Hotel, Tulsa.
- Nov.**  
12—South East Region, Birmingham, Ala.  
19-20—Western Region, Biltmore Hotel, Los Angeles.

### Million Dollar Savings on Oil Well Casing Damage Reported to Teche Section

Savings of over a million dollars in corrosion damage to oil well casings have been made by Stanolind Oil & Gas Co. as a result of applying cathodic protection to them. Jack P. Barret told members of Teche Section NACE at a dinner meeting September 8. The meeting was held at Lafayette with 10 members and 12 guests present. Mr. Barret, a member of the Tulsa section, spoke on Oil Well Casing Corrosion.

Three types of corrosion on oil well casings were covered, namely, electrolytic, galvanic and bacterial. Early investigators, Mr. Barret said, were hampered in determining and solving casing corrosion problems because they lacked tools and instruments. Now, however, it is possible to detect corrosion at depths of 1000 to 4000 feet. Stanolind is using both rectifiers and magnesium anodes, he reported. In one 9-well field, cathodic protection stopped corrosion on five, gave fair indication of retarding it on three and had no effect on one of the wells, he said. Mr. Barret illustrated his talk with slides and showed measuring instruments, potential curves and pH test samples. A question and answer period was held.

### New TP-15C Chairman

Robert Byrne, Association of American Railroads, Chicago has been named chairman of NACE Technical Practices Subcommittee 15-C on Corrosion Control in Railroad Hopper Cars.

Petitions for recognition as local sections of NACE have been approved for the Montreal Section and the Portland Section.

H. G. Burbidge, Aluminium Company of Canada, Ltd., Montreal has been appointed acting chairman of the newly formed Montreal Section. This is the fourth local section to be organized in the Canadian Regional Division.

C. E. Haney, Electric Steel Foundry Co., Portland, Oregon, has been appointed acting chairman of the Portland Section. The new Portland Section is the fifth local section to be organized in the Western Regional Division. Mr. Haney formerly was an officer of the San Francisco Bay Area Section.

### N. Texas Section Hears B. B. Morton in September

B. B. Morton, International Nickel Co., New York, was the speaker at a meeting of North Texas Section September 21, 1953. Mr. Morton's subject was "Some Moot Corrosion Problems." The program was arranged to encourage full audience participation. Members of the section were sent a list of questions to be studied prior to the meeting so they could be prepared for discussions at the meeting.

Questions were read at the meeting. Mr. Morton outlined some data bearing on them, and then, the chairman directed and encouraged discussion. It was expected by those planning the meeting that a large volume of information would be developed to help those in attendance.

### Short Course Delayed

Shreveport Section's annual corrosion short course has been postponed and is scheduled tentatively to be held in the latter part of October or first part of November.



Joe Duesterberg, left, technical speaker for the Houston Section's August meeting is shown greeting William A. Wood, Jr., Section program chairman. Mr. Duesterberg, of Plastic Applicators, Inc., Houston, spoke on Baked Phenolic and Rubber Linings in Corrosive Service. There were 74 members and guests at dinner.



## Cleveland Section Elects Palmquist As Chairman

Officers for the 1953-54 year have been named for the Cleveland Section. Elected were: Chairman William W. Palmquist, National Carbon Company; Vice Chairman Thomas H. Howald, Chase Brass and Copper Co.; Secretary-Treasurer Miss Jane Rigo, American Steel & Wire Co.; Program Chairman Harry W. Hosford, Jr., Harco Corporation, all of Cleveland.

Information on NACE's Corrosion Abstract Card Service may be obtained by writing to Central Office, 1061 M & M Bldg., Houston 2, Texas.

## San Francisco Section Hears J. J. B. Rutherford

Manufacture, applications and reasons for tubing failure were discussed by John J. B. Rutherford, chief metallurgist of Babcock & Wilcox Tubular Products Div., Beaver Falls, Pa. before 40 members and guests of San Francisco Bay Area Section. The dinner meeting was held September 9.

Mr. Rutherford conducted his listeners through an imaginary tube mill, and among other things gave detailed instructions on the proper approach to the inspection of tubes in service. His talk was received with enthusiasm and despite the late hour an informal question and answer period continued well over an hour after his talk ended.

## Interim Canadian Officers Confirmed

In a recent election the Canadian Regional Division of NACE elected for a full term all interim officers of the region appointed by the NACE Executive Committee when the region was formed. Elected for terms to expire on December 31, 1954 were: Chairman G. I. Russell, Trans Mountain Oil Pipe Line Co., Vancouver, B. C.; Vice Chairman L. W. Shemilt, University of B. C., Vancouver, B. C.; Secretary-Treasurer G. M. McPherson, Imperial Oil Ltd., Calgary, Alberta; Membership Chairman W. F. Croft, Koppers Products Ltd., Toronto, Ont. To serve on the board of directors of NACE as director for Canadian Regional Division is R. J. Law, International Nickel Co. of Canada, Toronto, Ontario.

## R. E. Shackelford

R. E. Shackelford, 47, general manager of Perrault Equipment Co., Tulsa, died in a Tulsa hospital August 25 after a paralytic stroke the previous night. Mr. Shackelford was an active member in the National Association of Corrosion Engineers and was affiliated with the pipeline business all his adult life. He had been with Perrault Equipment Company in a managerial capacity for eight years.

A native of Joplin, Mo., he attended the University of Oklahoma. He lived in Tulsa since 1930.

He is survived by his widow and one son, both of Country Club Heights, Tulsa; his mother, and two brothers, all the latter of Muskogee.

## Whitney Talks at N.Y.

Case Histories Illustrating Methods of Combating Corrosion was the title of a talk by F. L. Whitney, Jr., Monsanto Chemical Co., St. Louis before Metropolitan New York Section September 23. Mr. Whitney's talk was reported in error in September CORROSION to pertain to coatings.

## Maitland Talks on Cables at Buffalo

T. J. Maitland, American Telephone and Telegraph Co., New York City addressed a Western New York Section dinner meeting at Buffalo October 14 on "Control of Corrosion of Lead-Sheathed Cables in Non-Stray Current Areas. Also heard were "Coated Buried Pipe," by J. J. Meany of A. V. Smith Co., and "Corrosion Control Applied to Tower Footings," by Lloyd Yerger, Niagara-Mohawk Power Co.

A fellowship hour preceded the meeting.

Next Western New York Section meeting will be held jointly with Electrochemical Society of Niagara Falls on November 12.

Manuscripts of material on corrosion are accepted without invitation for review by NACE. Authors are advised to secure in advance of preparing their manuscripts a copy of the publication "Guide for the Preparation and Presentation of Papers," sent free.

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## Permian Basin Tour Schedule Is Given

The following schedule was prepared for the Permian Basin Section's corrosion tour:

### Wednesday, September 30

Registration, 7-8 am.  
Welcoming Address: Tom Newell, Cardinal Chemical, Inc., Odessa, 8-8:10 am.

Instructions: Lamar Sudduth, Stanolind, Midland, 8:10-8:20 am.  
Load Buses, 8:20-8:30 am.

Tours, 8:30-6 pm.  
Evening Sessions, 8-9:30 pm. Chairman: John Watts, Humble Pipe Line, Midland. Speaker: P. D. Phillips, Humble Pipe Line, Houston. Report of Group Leaders.

### Thursday, October 1

Load Buses, 8-8:10 am.  
Tours, 8:10-5 pm.  
Evening Sessions, 8-9:30 pm. Chairman: John Knox, The Western Company, Midland. Speaker (to be determined). Report of Group Leaders.

### Friday, October 2

Load Buses, 8-8:10 am.  
Tour, 8-12 noon.  
Barbeque, 12:30-1:30 pm.  
Exhibits, 1:30-5 pm.  
TP-18 Committee Meeting, 3 pm.  
**FIELDS:** Itan East Howard, Gold Smith, North Cowden, South Ward, Means, Fuhrman, Midland Farms, McElroy, Penwell, Jordan, Sand Hills, Crossett, Howard Glasscock.

**REFINERY:** Cosden Refinery, Big Spring, Texas.

## British Corrosion Group Holds 10 Meetings

Ten meetings, an exhibition and a works visit were held by the Corrosion Group, Society of Chemical Industry, during the year 1952-53. The group, which has completed its second year, now has nearly 300 members from 10 countries. J. C. Hudson of the Society of Chemical Industry Corrosion Group succeeds W. H. J. Vernon as president of the group.

Six of the ten meetings were held at London, covering such subjects as electrochemical behavior of metals, caustic cracking of steam boilers (at Institution of Mechanical Engineers. Proceedings to be published for general sale), tin-nickel alloy coatings, filiform corrosion, corrosion of aluminum and others. Meetings were held outside of London at Sheffield, Nottingham, Newcastle and Manchester.

The committee, which has been encouraging education on corrosion, reported also two courses were given and that some success has met efforts to have corrosion added to regular curricula. The Annual Reports on Progress of Applied Chemistry will contain as a regular feature a separate section on corrosion.

The committee also is in touch with Association Belge pur l'Etude, L'Essai et l'Emploi des Matériaux, and Centre Belge d'Etude de la Corrosion, with the U.S. and Canadian Inter Society Corrosion Committee and with the French Association of Anti-Corrosion Engineers. A joint meeting in Paris with Société de chimie Industrielle is under discussion.

## October 15 is Closing Date For 1953 Fulbright Awards

October 15 is closing date for receipt of applications for any of the Fulbright Award programs for university lecturing and advanced research in Europe and the Near East, Japan and Pakistan. Application forms may be obtained from Conference Board of Associated Research Councils, Committee on International Exchange of Persons, 2101 Constitution Ave., N. W., Washington 25, D.C.

Awards are available as follows: Foreign trade, English and American literature, Economics, International Relations and Political Science, Political Science, Sociology, International Relations and American History, Adminis-

trative Procedure, Education, Educational Philosophy, Music, Biology, Physics, Epidemiology, Surgical Anaesthesia, American Literature and English Language, Dentistry, Home Economics. Ten awards are available to research scholars. No indications to preferred fields is given but applications will be accepted in any field.

## To Talk at London

D. H. Lewis, vice-president of Shell Pipe Line Corp., Houston, is scheduled to address the Corrosion Group of the Society of Chemical Industry November 13 in London, England. The title of his talk will be "Economic Aspects of Underground Corrosion Control." The corrosion group is holding a symposium on cathodic protection on that date.

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# Twelve Technical Committees to Meet at Tulsa

In addition to five symposia and a round table discussion, twelve meetings of Technical Practices Committees and subcommittees have been scheduled for the NACE South Central Region 1953 meeting at Tulsa October 7-9 inclusive. The symposia will include five technical papers on oil and gas production corrosion problems; seven papers on pipeline corrosion problems; three papers on processing plant corrosion. An oil and gas transportation general round table discussion will be held.

All sessions will be held at Mayo Hotel, Tulsa. Registration will open at 8 a.m. October 7.

Nontechnical events scheduled are: Fellowship Hour, 6 to 7 p.m., October 7. Buffet supper and variety show, 6:30 p.m., October 8. Business luncheon, noon, October 9.

Technical motion pictures will be shown Wednesday morning, Thursday morning and afternoon and Friday morning.

## ADVANCE PROGRAM

### Technical Practices Committee Meetings

#### Tuesday Afternoon, October 6

- TP-1J Oil Field Structural Plastics, 1:30-3
- TP-1K Evaluation of Inhibitors for Use in Oil and Gas Wells, 3

#### Wednesday, October 7

- TP-1 Corrosion of Oil and Gas Well Equipment, 9 am-12 noon, and 2 pm-4 pm
- TP-6B Protective Coatings for Resistance to Atmospheric Corrosion, 9 am
- TP-18A Internal Sour Crude Corrosion of Pipe Lines and Tanks, 9 am
- TP-8A Corrosion by Gulf Coast Cooling Waters, 9 am
- TP-14A Electrical Holiday Inspection of Coatings, 9 am

#### Thursday Afternoon, October 8

- TP-17 Coating Conductance Measurement, 2-4
- TP-1H Corrosion of Oil String Casing, 2-4
- TP-1D Sour Oil Well Corrosion, 2-4
- TP-1G Sulfide Stress Corrosion, 3:30

#### Friday Afternoon, October 9

- TP-6E Protective Coatings in Petroleum Production, 1-2:30

### Technical Program

#### Thursday Forenoon, October 8

- Oil and Gas Production Symposium—1st Session. H. L. Bilhartz, chairman; Morris Bock, co-chairman.
- 9-9:40—Evaluation of Inhibitors for Gas Lift Wells—D. A. Shock and J. D. Sudbury, Continental Oil Company, Ponca City, Oklahoma
- 9:40-10:20—Evaluation of Ammonia for Control of Hydrogen Sulfide Vapor Zone Corrosion—A. C. Broyles and R. C. Sommer, Carter Oil Company, Tulsa, Oklahoma
- 10:20-11—Electro Chemical Studies of the Hydrogen Sulfide Corrosion Mechanism—Scott P. Ewing, Carter Oil Company, Tulsa, Oklahoma
- 11-12—Discussions.

Pipe Line Corrosion Symposium—1st Session. Robert L. Bullock, chairman; Marion J. Olive, co-chairman.

- 9-9:40—Cathodic Protection of Bare Pipe Lines in High Resistant Soils—R. C. Martin, Plantation Pipe Line Company, Atlanta, Ga.
- 9:40-10:20—Economics of Pipe Line Corrosion Mitigation—L. G. Sharpe, Humble Pipe Line Company, Houston, Texas
- 10:20-11—Cathodic Protection of Plant Yards with Distributed Anode Systems—B. J. Whitley, Jr., Tennessee Gas Transmission Co., Houston, Texas
- 11-12—Discussions.

#### Thursday Afternoon, October 8

- Processing Plant Symposium. Derk Holsteyn, chairman; Fred Prange, co-chairman.
- 2-2:40—A Study of Factors Affecting Heat Resistant Coatings—Joe Rench, Napko Paint & Varnish Works, Houston, Texas
- 2:40-3:20—Corrosion of Centrifugal Gas Compressor Phosphor Bronze Oil-Sealing Sleeves—Edward C. Greco, United Gas Corporation, Shreveport, Louisiana
- 3:20-4—Gasket Surface Corrosion—E. V. Kunkel, Celanese Corporation of America, Bishop, Texas
- 4—Discussion.

#### Friday Forenoon, October 9

- Oil and Gas Production Symposium, 2nd Session. W. F. Oxford, Jr., chairman; R. C. Booth, co-chairman.
- 9-9:40—The Use of the Nuli Bridge Method for the Classification of Corrosion Inhibitors—Norman Hackerman and B. L. Cross, University of Texas, Austin, Texas
- 9:40-10:20—Theoretical and Practical Aspects of Using Ammonia Injection to Prevent Casing Corrosion—H. L. Bilhartz, H. E. Greenwell and Rado Loncaric, Atlantic Refining Company, Dallas, Texas
- 10:20-12—Discussions.

Pipe Line Corrosion Symposium—2nd Session. R. A. Brannon, chairman; J. N. Hunter, Jr., co-chairman.

- 9-9:40—Internal Plastic Lining of Pipe in Place—M. B. Grove, Interstate Oil Pipe Line, Shreveport, Louisiana
- 9:40-10:20—The Need for Proper Cooperation in the Design of Corrosion Protection—C. A. Erickson, Peoples Natural Gas Company, Pittsburgh, Pa.
- 10:20-11—Experiences with Cathodic Protection on Montana Power & Light System—C. R. Davis, Montana Power & Light Company, Butte, Montana
- 11-11:40—The Effects of Impurities on the Performance of Magnesium Anodes—H. A. Robinson, Dow Chemical Company, Midland, Michigan.

#### Friday Afternoon, October 9

- Oil and Gas Transportation Symposium, A. L. Stegner, chairman.
- 2-4—General Round Table, Oil and Gas Transportation. Panel: L. A. Hugo, Ed. Doremus, W. E. Huddleston, Starr Thayer.

### Other Events

- Fellowship Hour, 6-7 pm, Wednesday, October 7.
- Buffet Supper and Variety Show, 6:30 pm, Thursday, October 8.
- Business Luncheon, 12 noon, Friday, October 9.

Technical Motion Pictures will be shown at the following times: 1-4 pm, Wednesday, October 7; 9-11 am, Thursday, October 8; 1-4 pm, Thursday, October 8; 9-11 am, Friday, October 9.

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## 28 Papers Listed on Non-Destructive Testing Society's Program

Twenty-eight technical papers are listed in the program of the Society for Non-Destructive Testing to be given October 19-22 at Hollenden Hotel, Cleveland. Also scheduled are presentation of the deForest Award to Magnaflux Corp., Chicago; Collidge Award to General Electric Company's X-ray Dept. and the Lester Honor Lecture by Adair Morrison of Arthur D. Little and Co. on "Field Application of Radiography."

Seven educational lectures are scheduled under the chairmanship of S. A. Wenk, Battelle Memorial Institute, on Monday, October 19.

Symposia will be held as follows:

Radiography — Monday, October 19, 2 pm.

Betatron Radiography, Tuesday, October 20, 9 am.

Isotopes and Problems of Non-Destructive Testing Here and Abroad—Wednesday, October 21, 9 am.

Ultrasonics—Wednesday, October 21, 2 pm.

Magnetic particle and Penetrant Inspection—Thursday, October 22, 9 am. Papers: Recent Developments in Penetrant Inspection, A. Robinson, General Electric Co., Thompson Laboratories; Factors in Use of Black Lights for Fluorescent Inspection by J. E. Clarke, Research Director, Magnaflux Corp.; Application of Magnetic Particle Inspection in Refineries by T. C. Wilson, Assistant Chief Inspector of Refineries, Sinclair Refining Co.; Role of Non-destructive Testing in Ford Motor's Quality Program by D. C. Hart, Quality Control, Ford Engine and Foundry Division, Ford Motor Co.

Eddy Current and Related Subjects, Thursday, October 22, 1:30 pm. Papers: Electronic Thickness Gage for Measuring the Thickness of Metallic Coatings by Abner Brenner, Chief, Electrodeposition Section, National Bureau of Standards, to be delivered by Jean Garcia-Rivera; Nondestructive Testing by Eddy Current Methods by Richard Hochschild, Physicist, Hanford Operations Office USAEC; Practical Nondestructive Testing with Conductivity by William A. Cannon, Jr., Engineer, Magnaflux Corp.

## New TP-18A Officers

John C. Watts, Jr., Humble Pipe Line Co., Midland, Texas, has been elected chairman and Randell L. Elkins, Shell Oil Company, Midland, co-chairman of NACE Technical Practices Subcommittee 18-A on Internal Sour Crude Corrosion of Pipe Lines and Tanks.

## 600 Attend Meetings

Attendance at three meetings held during the week of September 13 at the International Nickel Co., Inc., Corrosion Testing Station near Wilmington, N. C., was more than 600. The meetings included the 104th annual meeting of The Electrochemical Society, the annual Sea Horse Institute meeting and the Marine Borer Conferences.

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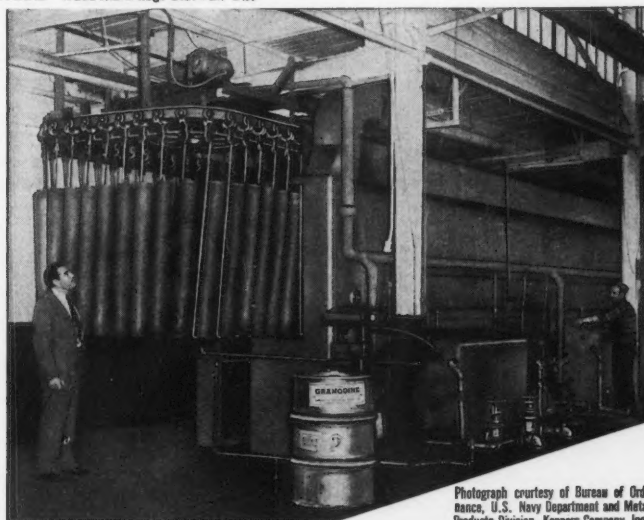
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Typical power spray washing machine for the automatic application of a protective phosphate coating to metal parts in preparation for painting. These 5" rocket motor tubes, as well as products made of cold rolled sheet steel, are effectively phosphate coated in such equipment.



## Many Papers Committed for Kansas City Program

The Oil and Gas Production Symposium and the General Corrosion Problems Round Table have been transposed in the March, 1954 Kansas City Technical Program. This change has been made in an effort to reduce the conflict of interest between simultaneous sessions at the times affected. The remainder of the program remains substantially as published in September CORROSION.

The Oil and Gas Production Symposium will be held on Thursday, March 18 from 9 to 11:30 am. The General Corrosion Problems Round Table will be held on Friday, March 19 from 9 to 11:30 am.

### More Papers Committed

Considerable progress is reported in commitments of technical papers. E. G. Holmberg, Alloy Steel Products Co., Linden, N. J. reports two sessions of this symposium are being considered for the presentation of eight papers. Four papers have been committed so far and three others are under consideration. Among those committed is one by W. G. Renshaw, Research Laboratory, Allegheny Ludlum Steel Corp., Brackenridge, Pa. on Passivating Characteristics of Commercially Pure Titanium.

S. A. Wenk, Battelle Institute, Columbus, Ohio says six papers are being solicited for the Symposium on Non-

Destructive Testing. Industrial fields to be covered are chemical, pulp and paper, marine, petroleum and testing services. A paper summarizing various available non-destructive testing techniques also is being considered.

### Three Papers Committed

R. C. Buchan, Humble Oil & Refining Co., Houston, chairman of the Oil and Gas Production Symposium has three papers committed for his symposium as follows: Corrosion Control of Creole's Lake Maracaibo Pipeline System by Frank Chuck; Survey of Corrosion Control in California Pumping Wells by Frank Davie and Preston Hill; Application of Radiotracers to the Study of Inhibitors in Corrosion of Steel by Oil Well Products by Paul Delahay, Jacob E. Strassner and Hassan S. Gamgoum.

Another paper being considered concerns sulfide corrosion cracking and a sixth paper also may be presented, Mr. Buchan said.

### Five Papers Committed

R. M. Lawall, American Telephone and Telegraph Co., Cleveland, chairman of the Power and Communications Industry Symposium has given the names of five papers and says a sixth paper will be presented by C. F. Avila, A. L. Schindler and A. B. Jones on corrosion of an underground cable system. The exact title has not been given.

The five papers committed are: Corrosion on the Keys by R. W. Ackerman, American Telephone & Telegraph Co., 138 East Court St., Cincinnati; Co-operative Test Methods for Corrosion Mitigation Problems in Urban Areas by D. T. Rosselle, Southern Bell Telephone and Telegraph Co., Hurt Bldg., Atlanta, Ga.; Some Experiences with Cathodic Protection in Chicago by L. M. Plym, Illinois Bell Telephone Co., 208 West Washington St., Chicago.

Positive Polarity Grounding of D.C. Supply Equipment in Mining Traction Systems by S. A. Gibson, Tennessee Coal and Iron Division, United States Steel Company, Fairfield, Ala.; Cathodic Protection of Power Plant Intake Screens by J. B. Prime, Jr., Florida Light and Power Co., Miami.

### Refinery Symposium Papers

E. H. Tandy, Standard Oil Co. of California, El Segundo, reports a timely and interesting solution to the problem of corrosion in domestic oil tanks is described in a paper by R. S. Treseder, Shell Development Co., Emeryville, Cal. This is a third paper for the Refinery Industry Symposium, which previously had been considered complete with two papers and a discussion session.

### Two Lectures Arranged

Two of the proposed three educational lectures have been arranged. R. C. Weast, Case Institute, Cleveland, chairman of arrangements for the lectures, said F. L. LaQue, The International Nickel Co., Inc., New York will talk on Design and Interpretation of Field and Service Corrosion Tests; J. J. Harwood, head of the Metallurgy Office of Naval Research, Washington will discuss stress corrosion. A lecturer on cathodic protection has not been selected.

Consideration is being given to presentation of motion pictures on the development and progress of stress corrosion cracking.

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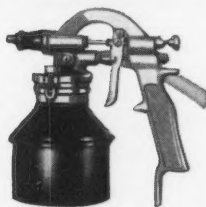
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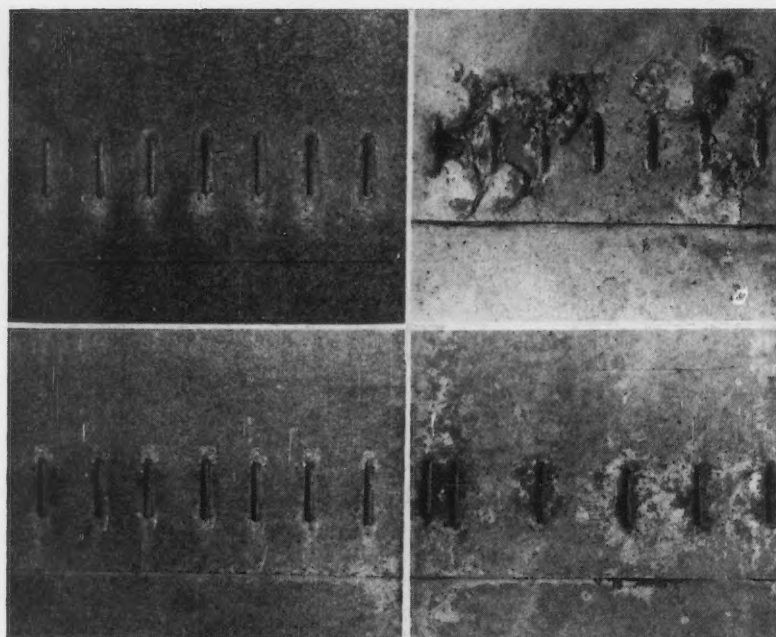


Figure 1—Specimens of galvanized-steel-stitched sheets of aluminum alloy studied for corrosion resistance by the National Bureau of Standards. The specimens at the left were exposed 37 months to a marine atmosphere, those at the right to the tidewater. The top two specimens are plain 24S-T3 aluminum alloy, while the bottom two are aluminum-clad 24S-T3. Results of the NBS investigation indicate that both alloys when fastened with galvanized steel staples have satisfactory corrosion resistance in marine atmospheres. For conditions of frequent wetting by sea water, however, only the alclad alloy proved satisfactory.

## Galvanized Steel Wire Stitching Adequate For Aluminum Alloys in Marine Environment\*

THE NATIONAL Bureau of Standards, at the request of other government agencies, has investigated the corrosion resistance of sheets of unclad and aluminum-clad 24S-T3 aluminum alloy stapled together with galvanized steel wire. Stapled specimen sheets of this high-strength aluminum-copper-magnesium alloy (containing about 4½ percent copper and 1½ percent magnesium) were exposed in a marine atmosphere and in the tidewater. Results for exposure periods up to 37 months indicate that both types of sheet joined in this fashion have satisfactory corrosion resistance for service in marine atmospheres. Where the installation is subject to frequent wetting by sea water, however, only the alclad alloy appears satisfactory. The bureau's study was conducted by Fred M. Reinhart of the NVS corrosion laboratory, under the sponsorship of the National Advisory Committee for Aeronautics, the Navy Bureau of Aeronautics and the Air Force Wright Air Development Center.

Galvanized-steel-wire stitching, or stapling, as a means of joining aluminum sheets has been used increasingly since early in World War II. Fast and economical, this relatively new method has given good results in the construction of non-load-bearing walls and partitions

in the interior of aircraft. Although the joints are not inherently as leakproof as those made by other methods, the use of suitable sealing materials can overcome this objection. Wire stapling of sheet metal is reported to have been extended more recently to non-aircraft applications, including interior panels in buses and in houses. Thermally insulated wall panels are readily fabricated by stapling layers of insulating material to the metal sheeting; a single stapling operation can fasten the insulation to the metal sheets as well as joining the sheets to each other.

In the NBS work, stapled panels of each material (24S-T3 and alclad 24S-T3) were subjected to intermittent sea-water immersion by exposing them in the tidewater. Other panels of each material were exposed in a marine atmosphere but not subjected to wetting. Panels were observed periodically and were removed for macroscopic and microscopic study after exposure periods of 6, 11, 22 and 37 months.

### Unclad Panels Deteriorate

The unclad 24S-T3 panels exposed to tidewater deteriorated rather rapidly. After two months in zinc coatings on the steel staples were white with corrosion. After six months the zinc was entirely gone from the staples, which by this time were covered with dark adherent rust. Microscopic inspection at six months showed that directly underneath the staples the sheets had cracked

by stress corrosion, the cracking having started at the faying surfaces of the sheets. By the end of 37 months the staples were badly rusted and pitted and the sheets in the area of the staples had suffered severe crevice corrosion, intergranular corrosion and stress corrosion cracking.

The alclad 24S-T3 panels stood up much better in the tidewater exposure. The attack on the zinc coating of the staples was much less severe. Even after 37 months some of the zinc-iron alloying layers were still present and the underlying steel had barely begun to pit. There were no corrosion products between the faying surfaces of the alclad sheets, indicating little if any crevice corrosion. Although most of the aluminum cladding had disappeared from the faying surfaces at 11 months, the core material had not been attacked even at 22 months. Only after 37 months exposure did the core show pitting and—but only in one area—stress corrosion.

### Marine Atmosphere Less Severe

When exposed in a marine atmosphere, there was very little corrosion of either the alclad or the unclad alloy, even after 37 months. The staples on both specimens were still coated with grey corrosion products, indicating that zinc or zinc-iron alloy layers were still present. None of the staples were significantly pitted. The faying surfaces of the 24S-T3 panel were slightly pitted, but no evidence of intergranular corrosion or stress corrosion cracking was found. The protective aluminum layers on the alclad 24S-T3 sheets were pitted at a few areas of the faying surfaces, but in no case had the pits corroded to half of the thickness of the layers. Crevice corrosion was quite mild—there were only small amounts of corrosion products between the faying surfaces of the unclad panels and practically none between those of the alclad panels.

Because of the crevice corrosion that developed, in varying degrees, at the faying surface of the joints, the application of a protective coating to these surfaces appears to be desirable for maximum service life as well as for leakproofing the joint. A non-absorbing type of sealing compound or paint can be applied to the joints either during or after the joining operation.

### Special Libraries Sessions

A two-day series of technical sessions and tours has been arranged for October 21-23 by the Special Libraries Association. The sessions, planned and sponsored by the Metals Division and Metals Section of the Science Technology Division, will be held at Cleveland during the National Metals Exposition. The association will present there also its display of current reference sources and services.

The technical sessions include the following papers of corrosion interest:

New Techniques in Welding, P. T. Stroup, Chief of the Process Metallurgy Division, Aluminum Company of America.

Materials for Use at Elevated Temperatures, W. J. Harris, Jr., Minerals and Metals Advisory Board, National Academy of Sciences.

Metallic Materials for Nuclear Reactors, Frank G. Foote, director, Metallurgical Division, Argonne National Laboratory.

\* For further details of the National Bureau of Standards study see "Exposure Tests of Galvanized-Steel-Stitched Aluminum Alloys," by Fred M. Reinhart, NACA Technical Note 2299 (1951).

## U. Cal. at Berkeley Schedules Marine Corrosion Conference

A two-day conference on Marine Corrosion Problems has been scheduled by University of California, Berkeley, for February 8-9, 1953. Topics included in the tentative program are environmental factors, biological factors, selection of materials, marine paints, cathodic protection, tanker corrosion, corrosion of laid-up ships and a panel discussion of special topics.

The purpose of the course is to discuss marine corrosion problems in a way to be of practical value to shipping, oil production departments, naval installations and port authorities. Those attending will generally understand the fundamentals of corrosion.

## Houston University's Paint Course Started

A two-semester, 4-hour-per-semester course on paint raw materials, characteristics and pertinent tests of paints is being conducted at the University of Houston with members of the Houston Paint and Varnish Production Club as instructors. The course may be taken for credit or not.

Some of the scheduled lectures are as follows:

September 14 — Orientation lecture, Clarence A. Wells, Humble Company.

September 21—Drying oils, John W. Garrett, Pittsburgh Plate Glass Company.

October 5—White pigments, Hollis Ballard, E. I. du Pont de Nemours & Co., Inc.

October 12—Extender pigments, R. S. Lamar, Sierra Talc & Clay Co., Los Angeles.

October 19—Rosin, natural resins and kindred products, Eugene Price, Crosby Chemical Co.

## Wisconsin U. Schedules Short Course in March

A corrosion control short course is being planned for March 24-26, 1954 by the University of Wisconsin, Madison. The university held a successful corrosion course during May of this year. Eastern Wisconsin Section NACE is assisting in the arrangements for the meeting.

## 1954 AWS Meeting

The 1954 National Spring Technical Meeting of the American Welding Society will be held May 4-7, 1954, in the Hotel Statler, Buffalo.

## Refrigeration Show

The Refrigeration and Air Conditioning Exhibition at Cleveland, November 9-12 will have displays by 225 companies.

Manuscripts of material on corrosion are accepted without invitation for review by NACE. Authors are advised to secure in advance of preparing their manuscripts a copy of the publication "Guide for the Preparation and Presentation of Papers," sent free.

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## S. Central Region to Be Invited to Meet At Houston Again

Plans to invite the South Central Region to hold an annual meeting in Houston were given the green light at the September 15 meeting of the Houston Section. On the technical program, Kenneth Tator of Kenneth Tator Associates, Coraopolis, Pa., explained the method used for "Evaluation of Paints and Coatings in Severe Atmospheric Exposures."

As coffee speaker, Cecil Grigg, backfield coach of the Rice Institute, football team entertained with explanations of the strength and shortcomings of the 1953 squad. In explaining coaching policy, Mr. Grigg said, "We like to win, but we try to make football fun for the boys, win or lose."

## REPRINT

Publication 53-I

### Surface Preparation Of Steels For Organic and Other Protective Coatings

- Second Interim Report of NACE Technical Practices Sub-Committee 6-G on Surface Preparation for Organic Coatings.

This report itemizes the various procedures used to prepare steels for the application of protective coatings. Recommendations as to procedures, standards, safety measures are given. This second report by NACE TP-6G is the culmination of many months of work by committee members. The report has been carefully prepared and checked by committee members with long experience in the coatings application field.

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## Field Testing Recommended

Mr. Tator said reference to the approximately 1400 case histories of surveys and evaluations he has made for clients is of great value to him in evaluating paint performance. But even though lacking this valuable reference aid, corrosion engineers can still do much to work out the problem by field testing for the right paint for the job, he explained.

The key to evaluating results of field testing is the chart Mr. Tator has devised which shows graphically as many as 120 combinations of types of coating failures. Mr. Tator has designed a special portable testing rack which can be handled by one man. This lessens labor costs for testing painted panels.

An accurate test for paints should duplicate as much as possible the actual conditions under which the paint will serve, Mr. Tator explained. Because paint failure begins with greatest frequency on sharp edges or corners and on projections such as rivet heads, Mr. Tator has constructed test panels which have these features reproduced. A section of channel iron is welded perpendicular to a flat surface. Such a test panel provides corners, weld areas and flat surfaces. In addition, by welding another piece of metal to the panel in a special way, Mr. Tator has devised a method of testing paint for crevice corrosion resistance.

## Correlation Is Important

One important part of testing paint performance is to correlate results from a test panel with performance of the same paint in actual service.

Generally, Mr. Tator explained, he will erect his stand of test panels near the tank, equipment, or article for which the paint is to be selected. However, he attempts to find an area where the corrosive atmosphere is more severe than that surrounding the article to be painted. This results in a slightly accelerated corrosion rate. By correlating corrosion rates and by keeping accurate charts on paints tested, Mr. Tator said he is able to predict paint performance in actual use with satisfactory consistency, usually within about 8 months.

More than 60 percent of the readers of CORROSION are engineers or do engineering work.

## Positions Available

**Chemical Engineer** — Familiar with materials of construction and corrosion problems to be technical staff man to evaluate and recommend; also develop methods for manufacturing chemical-proof equipment. Advise experience and salary desired. Heil Process Equipment Corp., Cleveland 11, Ohio.

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**Corrosion Engineers.** Positions available for graduate electrical engineers or equal. Previous field and design experience in corrosion mitigation systems required. Extensive travel involved. Salary open. The Hinchman Corp., Engineers, Francis Palms Bldg., Detroit 1, Mich.

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**British Chemical Engineer,** member NACE will be free presently to offer confidential liaison to manufacturer seeking to develop European markets. Experienced in assessing prospects, competition, manufacturing and selling costs. Sites located, plant erection supervised. CORROSION, Box 53-14.

**Research Engineer.** Considerable field, design, research and development experience for protection of communication cables, pipe lines, power substations, cables and transmission towers. West Coast preferred but travel considered. CORROSION, Box 53-15.

**Corrosion Engineer (BSGE),** 4 years experience with major design consultant; installation, maintenance cathodic protection systems for distribution and transmission piping, desires position with less travel demands. CORROSION, Box 53-16.

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## BOOK REVIEWS

**Pretreatment Specifications.** Published by Steel Structures Painting Council, 4400 Fifth Ave., Pittsburgh 13, Pa., March, 1953. Four 8-page pamphlets of 11 x 8 3/4 inches in loose leaf cover. Copy each Specification \$25c, set of four 60c.

Four pamphlets, each of which recommends an approved treatment for pretreating structural steel surfaces. First specification, Wetting Oil Treatment, defines wetting oils as penetrating oils that oxidize and air-dry to form a solid water insoluble, protective film. Wetting oil treatment is a method of initially saturating the surface layer of rusty and scaled steel with wetting oil that is com-

patible with the priming paint, thus improving the adhesion and performance of the paint system to be applied. This pretreatment does not, however, take the place of a coat of paint or eliminate the necessity of surface preparation.

Pretreatment No. 2, Cold Phosphate Surface Treatment is a method of converting the surface of steel to insoluble salts of phosphoric acid for the purpose of inhibiting corrosion and improving the adhesion and performance of paints to be applied.

No. 3, Basic Zinc Chromate-Vinyl Butyral Washcoat (sometimes referred to as wash primer) is a treatment specified for metals which reacts with the metal and at the same time forms a protective vinyl film containing an inhibitive pigment to help prevent rusting. This washcoat is supplied as two com-

ponents which are mixed together just prior to use. The base contains an alcohol solution of polyvinyl butyral resin pigmented with basic zinc chromate. The diluent contains an alcohol solution of phosphoric acid which reacts with the vinyl resin, the pigment and the steel. The fourth pretreatment, Hot Phosphate Surface Treatment covers the procedure required for the hot phosphate surface conversion of structural steel surfaces prior to painting. This gives a high temperature method of converting the surface of steel to a heavy crystalline layer of insoluble salts of phosphoric acid for the purpose of inhibiting corrosion and improving the adhesion and performance to paints to be applied.

**Symposium on Continuous Analysis of Industrial Water and Industrial Waste Water.** 54 pages, 6 x 9 inches, paper cover. June, 1952. American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.

Per copy .....\$1.50

Five technical papers on the continuous analysis of industrial water presented at the American Society for Testing Materials' meeting in New York City, June 24, 1952 are included. These papers are preceded by an introduction in which the need for continuous analysis is explained. Paper titles are: Automatic Sampling of Industrial Water and Industrial Waste Water, Some Practical Aspects of the Measurement of pH, Electrical Conductivity and Oxidation-Reduction Potential of Industrial Water, Continuous Recording of Chlorine Residuals and Determination of Chlorine Demand, Measurement of Color, Turbidity, Hardness and Silica in Industrial Waters, Continuous Measurement of Dissolved Gases in Water.

**Cathodic Protection With Zinc Anodes.**

28 pages, 8 1/2 x 11 inches, paper cover 36 figures. June, 1953. The American Zinc Institute, 60 East 42nd St., New York 17, N. Y. Per copy, Free.

This report, prepared for the American Zinc Institute by Ebasco Services, Inc., is intended to supplement the report "Zinc as a Galvanic Anode" published by the Institute in November, 1951. Additional design criteria included in the current report simplify engineering calculations of cathodic protection systems.

The report indicates galvanic anodes frequently are preferable to other impressed current systems when current requirements are small. Zinc anodes are recommended for use to protect well-coated structures in low and high resistivity soils. Characteristics of zinc provide more stable structure potentials than that provided by either rectifiers or magnesium anodes, the report indicates, with 30-year design life feasible.

Field tests on backfills are brought up to date and case histories on successful cathodic protection installations given.

Figures give considerable detail on engineering design, anode ratings and other information useful to the cathodic protection engineer.

**Bridgeport Condenser and Heat Exchanger Tube Handbook.** 6 x 9 inches, 156 pages. Illustrated, paper cover. 1953. Bridgeport Brass Co., Bridgeport, Conn. Availability not indicated.

This comprehensive book covers the (Continued on Page 16)



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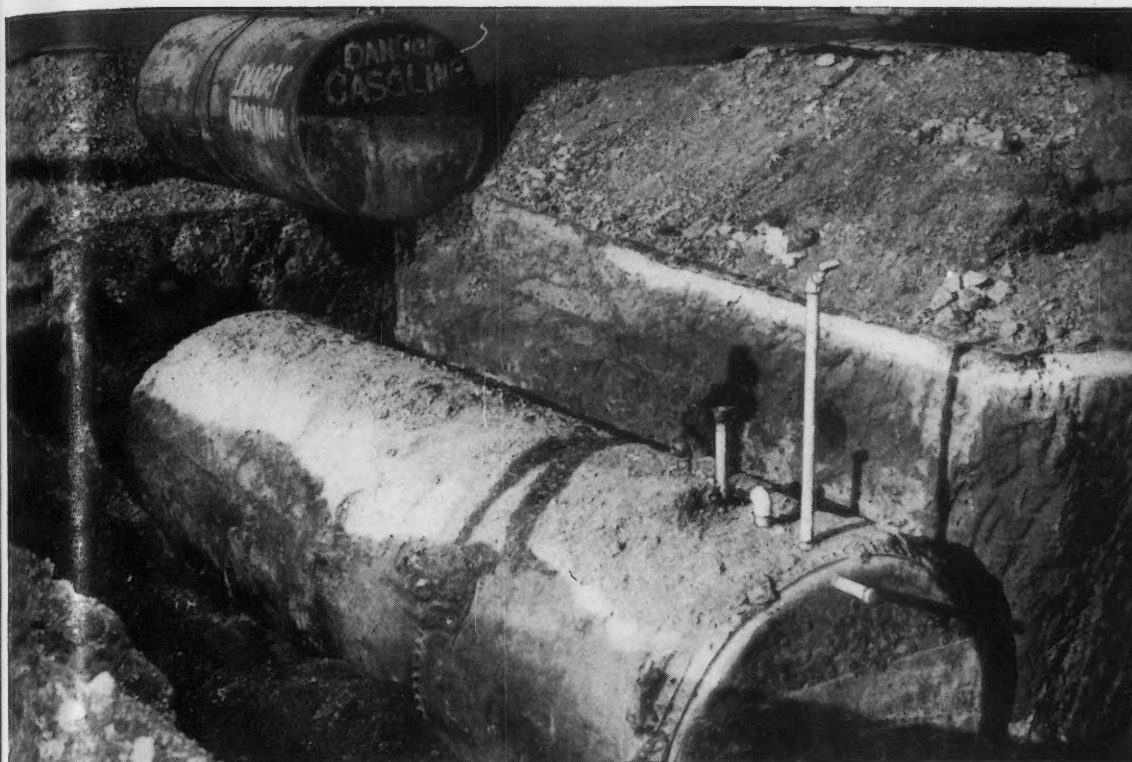
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**Adhesives, Coatings and Sealers**, an 8-page bulletin which lists the most important of these products produced by the Minnesota Mining & Mfg. Co., 423 Piquette Ave., Detroit 2, Mich., is available on request.

**Commercially Pure Titanium**, rolled in strips up to 8 inches wide and down to .0005-inch, to tolerances as close as plus or minus .0001-inch is available from Industrial Division, American Silver Co., Inc., 36-07 Prince St., Flushing 54m, N. Y.

**Cast-Iron Exhaust hood** of a 100,000 KVA steam turbine was sprayed with stainless steel to prevent erosion and corrosion of the iron from high velocity steam which had been causing water contamination. The metallizing eliminated contamination and was still good four years after application. This application was reported by Metallizing Engineering Co., Long Island City, N. Y.

**Stainless Steel** strapping for fastening insulating to piping and vessels is available from Acme Steel Co., 2840 Archer Ave., Chicago 8, Ill.

**Kaykor Industries**, a new division of Kaye-Tex Manufacturing Co., Yardville, N. J., has been organized to manufacture and provide technical service for rigid ployvinyl chloride, styrene copolymers and other industrial type thermo-

plastics for functional and decorative uses. V. C. Pierce is vice-president and J. L. Huscher, manager of technical sales and service.

**Corrosion Test Coupon Service**, consisting of furnishing cleaned, weighed test coupons to firms conducting testing programs and the cleaning, weighing and evaluation of the coupons after exposure is offered by C. J. Fritts & Assoc., P. O. Box 4603, Station A, Dallas, Texas.

**Karbate, Model 8A Standard Falling Film Absorbers** are described in a 12-page catalog section issued by National Carbon Co., a Division of Union Carbide & Carbon Corp., 30 East 42nd St., New York 17, N. Y.

**Crouse-Hinds Co.**, Wolf and Seventh North St., Syracuse 10, N. Y., has published a new 4-page bulletin, **SEC-K** on the firm's new EV2 series explosion-proof and weather resistant lighting fixtures. The lights are designed for use in concentrations of ethyl ether vapors or gasoline, petroleum, naphtha, alcohols, acetone, lacquer solvent vapors and natural gas.

**Sel-Rex Precious Metals, Inc.**, Belleville, N. J., announces a new copper purifier which eliminates the need for periodic dumping of copper plating baths by removing harmful solution breakdown impurities and converting them to useful cyanides.

**Positive Corrosion Control** is the title of a new 8-page illustrated booklet published by **Bart Manufacturing Corp.**, 227 Main St., Belleville 9, N. J. Typical samples of nickel-lined pipe, fittings and flanges are shown and the booklet discusses the **Bart Lectro-Clad** process and uses for nickel-lined steel pipe for corrosion protection.

**American Electro Products, Inc.**, 1358 Thomaston Ave., Waterbury, Conn., has developed the **Cantavone** controlled processes for volume electroplating. Among many applications of the electroplating is the use in prevention of corrosion from moisture, salt air, industrial fumes, contact with lubricants, extreme heat or cold and other causes.

**The Carpenter Steel Co.**, Reading, Pa., held an open house to celebrate opening of a new mill-branch warehouse and office in the San Francisco Bay area, 1530 Industrial Way, Belmont, Cal.

**The Cornelius Model 32R1500** air compressor will compress 70 cu. ft. of free air to 2350 psi in 100 minutes at 5000 rpm, according to the manufacturer, the Cornelius Co., 550 Thirty-ninth Ave., N. E., Minneapolis 21, Minn. The 3-stage compressor is designed to charge such industrial equipment and tanks such as the Scott Air Pack and similar gear for use by personnel during temporary exposure to noxious or poisonous fumes. The pump weighs six and a half pounds.

**Knapp Mills Inc.**, has published a new pamphlet describing nine new developments originated by the company. Among the processes described in the pamphlet are: The Cupralum Anode, of high conductivity copper to which a chemically bonded corrosion resistant lead cladding has been applied; The Ferrolum Anode, made of carbon steel to which lead cladding has been applied; Ferrolum Lead Clad Steel Immersion Heater for use with corrosive liquids. Knapp Lead-Plate Heaters, Universal Pipe Supporter, Automatic Lead Cladding Machine, Knapp Rasyst Compounds for containment of harmful radiation; Lead-Lube, a suspension of lead powder in a grease vehicle which lead

(Continued on Page 18)

## BOOK REVIEWS

(Continued from Page 14)

Bridgeport Brass Company's condenser tubes from the development of condenser tube alloys, through installation. Corrosion from water, impingement, dezincification, effect of temperature on corrosion, galvanic corrosion, effects of vibration on corrosion and the uses of duplex tubing in corrosive environments are covered in detail.

Many tables and graphs of data are given permitting comparison of the characteristics of several common types of tubes.

Numerous discussions of tubing installations in industry, including petrochemical, petroleum refining, chemical processing, sugar refining, refrigeration and steam power plants are given.

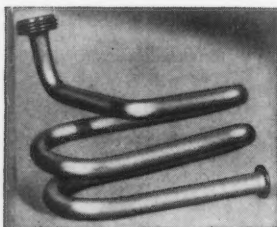
## STOP CORROSION LOSSES...

**Caused by Sulfuric, Nitric, Phosphoric Acids**

**Specify parts made of**

**ILLIUM**

**... the corrosion, erosion and heat resistant alloy**



Shown above is ILLIUM welded tubing. This small-diameter tubing is easily bent and flared to exact tolerances. It may be welded to itself or other metals, and retains its bright finish in service.



**The ILLIUM Utility Pump**  
A rugged pump designed for laboratory, pilot plant, and small industrial applications. Made entirely of ILLIUM, it will not contaminate material being pumped, and will often outlast stainless steel pumps as much as 5 times. Write for catalog information.

Critical processing operations involving corrosive liquids and gases have proved ILLIUM's ability to slash replacement and maintenance costs down to a minimum.

Unequaled in resistance to attack by all concentrations of sulfuric acid, at virtually all temperatures, ILLIUM is similarly well-suited to handling nitric, phosphoric, and mixed acids, and many acid-salt solutions. Over the years, it has firmly established its superiority over other alloys in the chemical, drug, petroleum, and food industries.

Available in castings up to 575 lbs., ILLIUM is easily machined and welded. Samples for testing and investigation will be sent on request.

**Write for Bulletin 651 for complete data.**

**THE ILLIUM CORPORATION, FREEPORT, ILLINOIS**  
Makers of Special Alloys and Quality Castings for Industry

# Parlon Stays On!

Long-term protection against chlorine and moisture ...

Mr. R. E. Ferguson, Master Mechanic at Southland Paper Mills, Lufkin, Texas, inspects wet end of Fourdrinier machine—protected with one coat of Parlon for twelve months. Plates in center have been wiped free of pulp to show excellent condition. This Parlon paint is Napko Durachlor, Southland Green #5110—applied over one coat Napko Red Oxide Metal Primer #1327, both made by Napko Paint & Varnish Co., Inc.



(Right) Metal railings and catwalks at D. M. Bare Paper Co., Roaring Springs, Pa., finished with two coats of Parlon paint applied in 1950. Paint is still in excellent condition despite condensation from live steam from pulp in area below. This Parlon paint is known as Tornesit, made by Perry-Austen Mfg. Co., Staten Island, N. Y.



(Above) At Scott Paper Company, Everett, Washington, four coats of a Parlon paint gives average service life of eight years on wooden bleach cell tubes in first-stage chlorinator. Parlon paint used is known as Paron, made by Petro Paint Company—a subsidiary of Rudd Paint & Varnish Co., Seattle, Washington.

In paper mills, where moisture and chemicals are constant enemies of processing equipment, paints made from Hercules Parlon (chlorinated rubber) are doing a remarkable job of cutting maintenance costs. Often they obviate installation of costly corrosion-resistant materials. Even chlorine finds its match in Parlon.

Parlon is easy to apply and serves equally well on metal, concrete, wood, and special surfacings. It

dries almost as fast as lacquer, and is highly resistant to wear and abrasion as well as to acids and alkalis.

If corrosion is a particular problem with you, specify "paints made with Parlon." In paper and textile mills, chemical plants, refineries, sewage disposal plants, and water works, ships, and railroads ... Parlon gives better service at lower long-term costs. See your regular supplier for details on Parlon-based paints or write Hercules.

Cellulose Products Dept. **HERCULES POWDER COMPANY** 999 King St., Wilmington 99, Del.

**LOOK FOR THIS LABEL  
ON THE PAINT CAN...**

MADE WITH

**Parlon®**

HERCULES® CHLORINATED RUBBER

PARLON CHLORINATED RUBBER PAINTS ARE AVAILABLE FROM 400 MANUFACTURERS UNDER THEIR OWN BRAND NAMES

CR53-4

**Saran  
rubber  
CAN'T  
rust...  
CAN'T  
corrode**

that's why  
leading engineers choose  
**MPC SARAN RUBBER\* LINED  
STEEL PIPE**  
wherever corrosion is a problem!



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sure you're  
getting the  
highest de-  
gree of re-  
sistance to  
corrosive chem-  
icals, oils, acids  
and solvents when

**MPC SARAN RUBBER-LINED STEEL  
PIPE** is specified. Available in either  
fabricated light gauge steel or stand-  
ard steel pipe in 10' and 20' standard  
lengths, ranging in size from 8" up . . .  
or fabricated to your exact require-  
ments. Fittings in standard and special  
designs for all diameters.

For additional information write today  
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to our application engineering depart-  
ment.

You can lick corrosion. It's as easy as  
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\*a development of  
The Dow Chemical  
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**MICHIGAN PIPE COMPANY**

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Manufacturers of Wood-Lined Steel, Saran Rub-  
ber-Lined Steel, Stainless Steel and Monel Pip-  
ing. Represented nationally by Saran Lined Pipe  
Co., Detroit, (Ferndale) Michigan.

## NEW PRODUCTS

(Continued from Page 16)

coats wearing surfaces and the Guidler, a combination idler and guide to protect conveyor belt edges.

**The Holocal Mfg. Corp.**, Box 95, Belle-rose 26, L. I., N. Y., is producer of the Bel Connector, a cast-iron fitting to seal pipe leaks quickly without cutting off the flow in the pipe. The connector is made in two semi-circular parts joined by four screws. It is designed to enclose the leak within captive Neoprene gaskets when the screws are tightened.

**The Mobile, Alabama** plant of Eagle Chemical Company, Joliet, Ill., has reached full production of clay desiccants, according to a company announcement. Clay desiccants are a relatively new development, according to the firm and the comparative efficiency of clay and its lower cost has resulted in a substantial demand, it is said.

**Plax Corp.**, West Hartford, Conn., has issued an 8-page illustrated brochure on unbreakable 6½ and 13-gallon Plaxpak Polyethylene carboys. Specifications for both jacketed and unjacketed carboys are listed in tabular form. Among features claimed are: safety, light weight, lowered shipping costs, ability to handle most corrosives and reduced replacement costs.

**The Superior Tube Co.**, Norristown, Pa., is installing a vacuum furnace for annealing tubing of titanium and zirconium. The new furnace is the batch type, can handle tubing in lengths up to 24 feet. Company engineers say that because titanium presents many metallurgical problems not encountered with other metals, the seemingly simple task of producing small tubing from this metal on a commercial basis required 6 years of development. The titanium tubing is produced in Seamless and Weldrawn (welded and drawn) construction.

**Corrosion Inhibition** will be covered at a session concurrent with one on chemical agriculture at American Chemical Paint Co., International Division, Ambler, Pa. Attending the sessions will be delegates from 40 countries. The delegates are to meet U. S. government officials for an exchange of ideas on the problem of cooperation with North Atlantic Treaty Organization and Mutual Security Agency programs designed to maintain defenses of the Free World and increase its food supply, as these problems affect the fields of corrosion inhibition and chemical agriculture.

Several subjects of corrosion interest were scheduled for discussion at the convention. "Corrosion in Action," the well known International Nickel Co. film was to be shown. Acid Cleaning; Alkaline Cleaning Processes; Inhibitors—Development, Testing, etc.; Inhibited Pickling in Production, Phosphate Coatings; The Painting of Metal; and other like topics were subjects of papers. The meeting was scheduled for Sept. 21-26, and, according to a news release, copies of the papers would be available.

**Nickel Alloys** in Railroad Equipment, an illustrated 32-page brochure available

from The International Nickel Co., Inc., 67 Wall Street, New York 5, N. Y., gives data on the uses being made of nickel materials in Diesel-electric, electric and steam locomotives, gas turbines, passenger equipment, freight cars and miscellaneous railroad applications.

**Applications Unlimited**, a 16-page brochure describing and illustrating the uses of beryllium copper, is available on request from The Beryllium Corp., Reading, Pa.

**Metablast**, a technique for surface preparation whereby an abrasive suspended in liquid is directed against the surfaces to be cleaned or prepared, produces a surface which is ready for electroplating, for instance, as soon as removed from the blasting cabinet. The method makes possible the removal of hard crusts, rust, scale, old paint, platings or other coatings from such items as water meter parts.

**Where Tars Come From**, a 40-page brochure explaining the origin of coal, describing the different varieties of coal, and their respective uses, the production of coal tars and other products from coal, coal mining operations, coke production, is available from Koppers Co., Inc., Pittsburgh. This well-illustrated non-technical exposition on coal is a clear explanation of the coal by-products industry.

**Allyl Chloride** and epichlorohydrin will be produced at Shell Chemical Company's new Norco, La., plant. Its output will be used to increase Shell's glycerine production by 25 million pounds annually and also Shell's Epon resin output.

**Van-Cor** pipe and fittings will be handled by Texas Plastic Development Company, 3638 University Blvd., Houston.

**Hard Coatings** of aluminum alloys by the MHC (Martin Hard-Coatings) Process, is the exclusive business of Anodic, Inc., Salt Street, Bridgeport, Conn. The company holds a commercial license from Aluminum Company of America. The coating, generally .002-inch thick, consists of an amorphous coat of aluminum oxide about ten times thicker and 30 to 100 percent harder than other anodized coatings. Because the coating grows equally above and below the surface, .002-inch coating increases dimensions only by .001-inch. Build up is consistent on both surface and undercut areas and can be controlled closely. Greatest current interest is among manufacturers of office machines, textile machines, gages, gears, valves, hydraulic pistons and cylinders, guide rods, plates and materials subject to corrosion. The coating has stood a 5000-hour salt spray test. It has high dielectric strength and varies from amber to black depending on the type of alloy coated.

**Plate Type Heaters** made of lead for uses involving corrosives such as sulfuric, phosphoric, chromic sulfurous acids, sulfates and others are manufactured by Knapp Mills, Inc., 23-15 Borden Ave., Long Island City, N. Y. They are available in surface areas of 6.6, 9.9 and 13.2 square feet, and are recommended for 10 pounds of steam or less. Special units will be designed on request.

(Continued on Page 20)



# SOMASTIC★ PERMANENCE

includes TIME TESTED METHODS of Application



For the past 23 years SOMASTIC PIPE COATING has been applied to pipe by standard practices which only now are being adopted generally by the pipe coating industry. Time has proved them most effective. These methods are—

- ★ *Thorough cleaning of metal by grit-blasting.*
- ★ *Pre-heating, followed by hot priming, assuring a firm, lasting bond of coating to steel.*
- ★ *Selection of materials and manufacture of coating to rigid specifications.*

In addition, SOMASTIC leads in this essential feature—

- ★ *Application of coating to primed pipe in a continuous process by special SOMASTIC equipment to form a dense, compact, uniform and seamless protective coating of great durability.*

The general swing to methods pioneered by SOMASTIC Pipe Coating is another acknowledgment of a fact first shown by the API-Bureau Of Standards Ten Year Pipe Coating Tests... and since proved at thousands of corrosive locations... for *permanence* coat with SOMASTIC.

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## PIPE COATING

**Unequaled for PERMANENT PROTECTION**  
**SOMASTIC IS The Best PIPE COATING**

MANUFACTURED BY

**H. C. PRICE CO.**  
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 In the 37 States East of the Rocky Mountains

**BECHTEL CORPORATION**  
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 In the 11 Western States and in Foreign Countries

## TRIPLE THREAT AGAINST CORROSION . . .



Beat the high cost of corrosion with proven, genuine Haveg pipe and fittings. Pipe highly corrosive fluids in temperatures as high as 265 degrees F. with a good margin of safety! Since Haveg is not a coating or lining, the possibility of contamination is eliminated.

Haveg is a moldable, thermosetting plastic made by mixing acid-digested asbestos with special resins. Haveg process equipment is unusually resistant to most acids, salts, chlorine, many solvents . . . and withstands extremely high thermal shock. Haveg is really a triple threat against corrosion!



Send for 64-page Bulletin F-6. It contains complete information on Haveg pipe, fittings, valves, pumps, cylindrical and rectangular tanks, heat exchangers, and other corrosion-resistant process equipment. Call your Haveg sales engineer for first-hand facts.



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SEATTLE 7 Hemlock 1351 ST. LOUIS 17 Hilland 1223

\* A Subsidiary of Continental-Diamond Fibre Company.

SEND FOR 64-PAGE HAVEG BULLETIN F-6.

## NEW PRODUCTS

(Continued from Page 18)

**Barco Manufacturing Co.**, Barrington, Ill., has published a new bulletin describing insulating joints for piping lines to electrolytic plating, cleaning and anodizing tanks used by metal working industries. The joint provides an electrical insulating barrier in a pipe without interfering with its capacity or efficiency. The joints are often used in preventing pitting or corrosion due to electrolysis. Joints are available in sizes from one-quarter inch to six inches, with temperatures to 425 degrees F and 300 psi, or up to 2000 psi for smaller sizes.

**Conpor**, oil seals and packings made of leather impregnated with Thiokol are being produced by the Chicago Rawhide Manufacturing Corp. The seal retains the good properties of leather, yet gives proper control of porosity. The Thiokol impregnant is insoluble in oil, does not melt or deteriorate at operating temperatures, is flexible and ages well. Conpor is produced in two categories—full and limited depth impregnations. In each category several porosities are available. Thiokol is made by the Thiokol Chemical Corp., Trenton, N. J.

**Hanson-VanWinkle-Munning Co.**, Matawan, N. J., has completed experimental studies on the use of electroplated films to improve the process of hot galvanizing strip steel by protecting the treated surfaces of the steel prior to coating. The company claims experiments show that a film of electroplated non-ferrous metal can retard and possibly prevent the formation of harmful iron oxide on the surface. The new step is not costly, the firm states.

**Premier Master Vac**, 755 Woodlawn Ave., St. Paul 1, Minn. has published literature on its Model 150 heavy duty blower and hand cleaner. The literature illustrates blower and accessory tools, shows applications and specifications for the equipment and pictures kits available to convert the equipment for specialized uses.

**Atlas Powder Co.**, Industrial Chemicals Dept., Wilmington 99, Del. has developed a new rust inhibiting oil additive. Atpet 100, the new inhibitor is a sorbitan mono fatty acid ester. It is shipped as a concentrate for addition by the refiner or compounder to his oil. A greater degree of protection than other non-metallic inhibitors and consistently uniform protection is claimed. Samples and literature are available.

**New Explosion-Proof**, dust-tight fluorescent lighting fixtures designated Type EVF, have been developed by Crouse-Hinds Co., Syracuse 10, N. Y. The new fluorescent fixtures are designed for use wherever the presence of explosive gases or vapors or combustible dusts requires safe, practical lighting.

**Schori Process Division of Ferro-Co. Corp.**, 8-11 43rd Rd., Long Island City, N. Y., announces the manufacture of crocks made of Iolyte, a Fiberglas reinforced polyester laminate. Iolyte crocks are chemically-resistant structural plastic that cannot break or crack as glass and ceramic crocks do, it is claimed. Iolyte crocks are available from

stock in capacities ranging from 5 to 125 gallons; diameters from 9 inches to 28 inches; heights from 12 inches to 48 inches.

**Tube Turns, Inc.**, 224 E. Broadway, Louisville 1, Ky., has established a branch plant at 7120 Katy Highway, Houston. The firm manufactures Tube-Turn welding fittings and flanges.

**General Ceramics and Steatite Corp.**, Chemical Equipment Div., Keasbey, N. J., are marketing new ceramics for high and low alloys, aluminum and carbon steel. High temperature protection against corrosion and erosion and the substitution of cheaper metals are main advantages of the ceramic coatings. Samples and prototypes may be obtained from the company.

**Koppers Co., Inc.**, will build a plastics development plant at the site of its large Kobuta chemical plant. It will produce semi-commercial quantities of a wide variety of new plastics.

**Electro-Galvanized tubing** with a bright outside surface said by the manufacturer to have unusual corrosion resistance is manufactured by National Electric Products Corp., Gateway Center, Pittsburgh, Pa. Inside surfaces of baked on aluminum enamel have minimum resistance to wire pulling, tests made by the firm indicate. Fittings with the same finish and corrosion resistance are available.

**A New Standard Line** of pressure heat exchangers designed to pass corrosive liquids or gases under pressure at high temperatures through tubes or shell is now being produced by Haveg Corp., Marshallton, Del. Molded from Haveg, an acid-digested asbestos bonded with synthetic resins, the exchangers are available in sizes from 13½ to 29¼ inches ID with single or multi-pass interchangeable heads. Larger sizes up to 10 feet in diameter may be made for coolers and low-pressure heat exchangers. Pressure range of the new line is from 50 to 75 psi. It is safe to use at temperatures up to 265 degrees F. Special corrosion resistant pumps, valves and fittings are available also.

**Dow-Corning XR-807**, a silicone based resin, which can be pigmented in the usual manner, used clear, or blended with urea or melamine formaldehyde resins is available from Dow Corning Corp., Midland, Mich. The coatings, which may be air dried or baked, are said by the manufacturers to be superior in weather and sunlight resistance to any conventional organic finish. Tests of film integrity, adhesion and weather resistance at surface temperatures as high as 750 degrees F have been made successfully. Technical data sheets giving applications, description, and suggested formulation are available.

**Passivation** of copper and most copper alloys with a single dip and rinse process is easily made with Rossaul Copper-Brite, the manufacturers Rossaul Co., 170 Fifth Ave., New York 10, N. Y., claim. The dip removes oxides and passivates the metal so that it will resist oxidation from 3 to 6 months, dependent on atmospheric conditions. It is non-toxic, non-fuming, will not discolor silver solder and will not etch.

(Continued on Page 22)

## THIS INSUL-MASTIC COATING COST NOTHING...

*It actually paid for itself in one year*

The photograph shows INSUL-MASTIC TYPE "D" being applied on an oil tank that is kept heated to retain free flowing viscosity. Within one year after the completed application this coating of INSUL-MASTIC TYPE "D" prevented enough heat from escaping from the tank to pay for the cost of the coating. It also prevented corroding of the tank.

INSUL-MASTIC TYPE "D" is a *Superior* quality corrosion preventive coating to which we add considerable cork. We then apply it  $\frac{1}{4}$  inch thick. It is not intended to replace standard thermal insulation, but on vessels where moderate temperatures are maintained it stops much heat loss while preventing corrosion.

Applications as old as fifteen years have never required maintenance.

*Write for further information.*

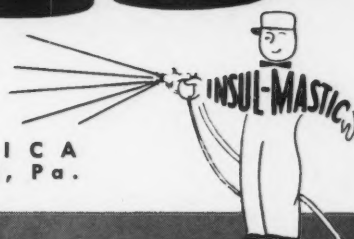
To vaporseal thermal insulation specify INSUL-MASTIC 4010. Our technical engineers are available to help you with this and other coating specifications.

*Think first of the coatings that last!*



# Insul-Mastic

CORPORATION OF AMERICA  
Oliver Building • Pittsburgh 22, Pa.  
Representatives in Principal Cities





## NEW PRODUCTS

(Continued from Page 20)

**Menlo Research Laboratory**, Box 522, Menlo Park, Calif., has developed a compact new Blacklight Wand, a portable, ultraviolet instrument. The "wand" is used by metal products engineering and manufacturing firms for leak detection and materials flaw or crack tests. It also has many other uses. The "wand" weighs only one and three-quarter pounds.

**Klem Chemicals, Inc.**, 14401 Lanson Ave., Dearborn, Mich., has published a new catalog for use by metal processors and finishers to aid in selecting correct chemicals for various operations. The 33 standard Klem products are listed, and the catalog contains a comprehensive application chart for surface preparation of ferrous and non-ferrous metals. Klem's laboratory facilities for compounding special chemicals for unusual conditions have also been described.

**Hysol Masonry Paint**, a new coating based on Pliolite S-5, a synthetic rubber resin of the Goodyear Tire and Rubber Co., has been added to the group of coatings manufactured by Houghton Laboratories, Inc., of Olean, N. Y. The paint is said to provide a maximum protection against alkali reaction from chemicals present in concrete and masonry, plus an effective moisture barrier that prevents cracking and flaking.

**Sherwin-Williams Co.**, Cleveland, Ohio is constructing plants in Venezuela and Mexico. The firm already operates plants in Brazil and Argentina.

**American-Marietta Co.**, 101 E. Ontario St., Chicago 11, Ill., has acquired controlling interest in the Universal Concrete Pipe Co., Columbus, Ohio. The firm makes all kinds of precast concrete forms, and also makes prestressed concrete bridge sections, Tunneliner and Lo-Hed pipe.

**Atlas Mineral Products Co.**, Mertztown, Pa., has developed two new types of rigid polyvinyl chloride pipe and pipe fittings. One new product is said to have high chemical resistance, and the other high impact strength. The pipes are available in sizes from one-half inch to four inches. Molded fittings are available in sizes from one-half inch to four inches. Molded fittings are available for pipe up to 2 inches IPS and fabricated fittings are available for larger sized pipe. The high chemical resistant pipe will be marketed under the name of Ampcoflex, and the high impact pipe under the name, Pee Vee Cee.

**North American Philips Co., Inc.**, 750 S. Fulton Ave., Mt. Vernon, N. Y., is producer of a new "Norelco" flat plate camera, designed especially to provide a high degree of utility in meeting present-day needs of X-ray diffractionists. Major application is said to be in the study of metals.

Reprints of material published in Corrosion are usually made only on order. Tentative prices may be obtained from Corrosion, 1061 M & M Bldg., Houston 2, Texas.

## PERSONALS

**Samuel E. Bosley** has been appointed Petroleum Industry Specialist by Owens-Corning Fiberglas Corp. For five years the company's Tulsa branch manager, he will remain at Tulsa but will cover Northern Texas, Louisiana and Oklahoma.

**William G. Gerstacker** has been appointed chief engineer of Heil Process Corp., Cleveland.

**B. Otto Wheeley** has been named Southern District Sales Manager for the Tar Products Division of Koppers Co., Inc. He formerly was assistant district manager with headquarters at Birmingham, Alabama.

**Sam B. McWhorter** has joined Lithcote Corp., New York City, as a chemical engineer.

**Norman Hackerman**, professor of chemistry at the University of Texas has been named a consultant in hydrogen bomb production for the Atomic Energy Commission.

**Clayton L. Heintz** has been named manager of distribution of Cooper Alloy Foundry Co., Hillside, N. J.

**Arvin W. Harrington** is now sales representative for Carpenter Steel Company's Alloy Tube Division in metropolitan New York.

**Frank J. Hodnick** has been named ceramic research engineer by Solar Aircraft Company. He will study utility type coatings to protect low alloy steel against corrosion.

**Edward H. Platz, Jr.**, Lebanon Steel Foundry, Lebanon, Pa., is the new chairman of the Alloy Casting Institute's public relations committee. **C. M. Ruprecht**, Electro-Alloys Division, American Brake Shoe Co., Elyria, Ohio and **Brad B. Evans**, Empire Steel Castings, Inc., Reading, Pa., are committee members.

**W. C. Stratton** has been appointed superintendent of design of Ebasco Services Incorporated's Design Div. Mr. Stratton will supervise all Ebasco design and drafting activities. In another appointment **H. T. Canfield** was made assistant construction manager of the Construction Div. of Ebasco Services Inc. He will be responsible for coordinating all functions relating to the engineering, construction and business consulting firm's New York office construction activities.

**William J. Thomas**, formerly general sales manager, has been appointed general manager of the Tubular Products Div., The Babcock & Wilcox Co., and **Paul J. Utnehrmer**, works manager, has been named to the board of directors of the division.

**Leon M. Wheatley** has been named vice-president of the R. M. Hollingshead Corp., according to an announcement by **Wilbur H. Norton**, president of the firm.

**J. B. Froblom** will specialize in the sales and service of atmosphere control furnaces in his new job with the James H. Knapp Company, Los Angeles, Calif.

**Henry C. Earle, Jr.**, has been appointed sales manager of The Annin Company, Los Angeles, manufacturers of control valves.

**Herbert J. Sherertz**, Greensboro, N. C. has been named assistant textile research representative at American Viscose Corporation's acetate plant at Meadville, Pa.

**Harry L. Holstrum**, since 1924 with Republic Creosoting Co. and Reilly Tar & Chemical Corp., Minneapolis, Minn., has been named plant manager.

**Albert J. Anderson** and **Philip A. Bjorkman**, Cal-Seal Co., No. 9 Sutter St., Room 504, San Francisco, now represent Protective Coatings, Inc. of Tampa, Fla., and Cleveland, Ohio, in the states of California, Arizona, Oregon and Washington. **John B. Taylor**, 2425 Farragut Ave., Chicago will represent the firm in the northern part of Illinois, most of Wisconsin and the upper tip of Michigan.

**H. R. Bennett**, 57, vice president and director of Union Producing Company of Shreveport, La., and a director of United Gas Pipe Line Co., died in August of a heart attack while playing golf at the Shreveport Country Club. Mr. Bennett formerly lived in Houston while he was an executive with the Mills-Bennett Producing Company for about 16 years. He had held various executive positions in producing departments of the oil and gas industry during the last 30 years. He was a member of NACE and several other technical and social organizations.

**Julius J. Harwood** has been appointed Head of the Metallurgy Branch of the Office of Naval Research, Navy Department. Mr. Harwood replaces Dr. O. T. Marzke who has returned to the Naval Research Laboratory as Associate Director. Mr. Harwood has been with the Office of Naval Research since 1946 and during the past several years has served successively as Assistant Head and Deputy Head of the Metallurgy Branch.

Appointment of three department heads as well as other appointments was announced by **Dr. Karl Cohen**, vice-president of Walter Kidde Nuclear Laboratories, Inc. The new department heads were: **Dr. Cecil B. Ellis**, Research Department, Laboratory Division; **J. J. Byrnes**, Engineering Department, Laboratory Division; and **Karl Puechl**, Theoretical Department, Development Division.

**W. D. Sullivan**, assistant works manager of the Tubular Products Division of the Babcock & Wilcox Co., Beaver Falls, Pa. has been transferred to the company's Boiler Division as regional manager.

**Henry R. Hogendobler**, formerly industrial insulations sales manager of Owens-Corning Fiberglas Corp., Toledo, Ohio, has been named vice-president and general manager of the Fiberglas Contracting and Supply Co., Cincinnati, Ohio. He succeeds **Lee R. Reeder** who has resigned.

**R. H. Cubberley**, formerly assistant research director has been named director

(Continued on Page 23)

## PERSONALS

(Continued from Page 22)

of research for all divisions of the Flint-kote Co. He will make his offices at the firm's research laboratory at Whippany, N. J.

Appointment of **D. C. Sanford** to the position of manager of the application Engineering Dept. of the Bristol Co., Waterbury, Conn. has been announced. Mr. Sanford will continue to make his headquarters in Waterbury, Conn. In another appointment, **F. W. Borchers** was made general sales manager of the company.

**P. L. Coddington** has been appointed assistant to the president of The Carpenter Steel Co., at the firm's Alloy Tube Division, Union, N. J. Mr. Coddington had been manager of sales since 1945, and had been active in the steel industry for more than 25 years. **William R. Staples**, formerly assistant manager of sales was appointed to the post formerly held by Mr. Coddington.

**John J. Stobie, Jr.**, sales engineer in the Chicago home plant of Apex Smelting Co., has been transferred to the company's new million-dollar Los Angeles plant in a similar capacity.

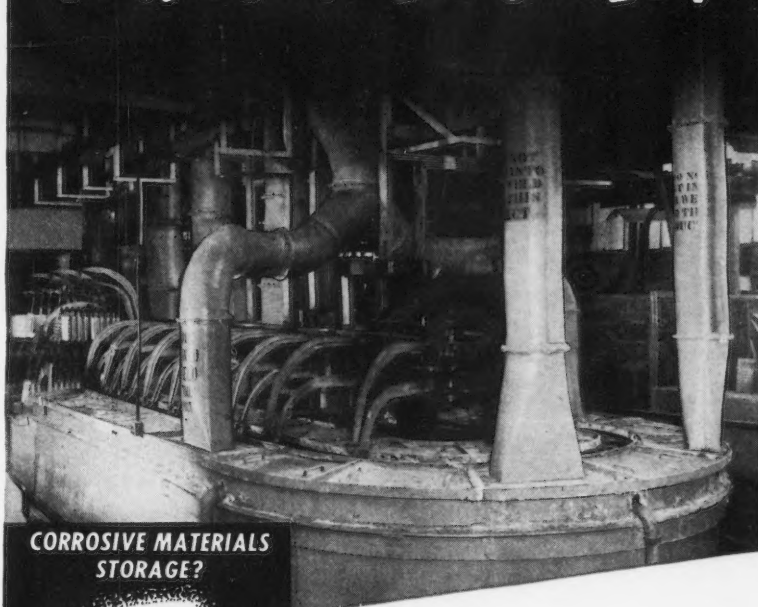
**Virgil C. Reed** of Houston has been appointed field representative for the Southeastern and Southwestern states by the Alloy Rods Co., York, Pa., manufacturer of alloy arc welding electrodes. Mr. Reed will make his headquarters in Houston.

The **Cleaver-Brooks Co.** of Milwaukee, Wis. has appointed as manufacturers representative, the **D. E. McCulley Co.**, Omaha, Neb. Cleaver-Brooks manufacture equipment for generating and using heat.

**H. F. Trusler, Jr.**, and **M. E. Maddox** have been appointed to sales positions for the Protective Coatings Div. of the Pittsburgh Coke and Chemical Co., Pittsburgh. Mr. Trusler will work in New York City, and Mr. Maddox in Atlanta, Ga. The firm markets tar base pipe line enamels, cold applied tar base coatings and other special types of industrial protective coatings and finishes.

Recent changes have been made in the staff of **Leo V. Steck**, marketing vice president of Shell Chemical Corporation, as follows: **J. J. Lawler**, formerly district manager in Chicago, takes up new duties as sales manager for the company's **Julius Hyman & Company Div.**, Denver, Colo. **J. K. Robbins**, formerly district manager at St. Louis, replaces Mr. Lawler. **W. C. Lowrey**, formerly manager of the Eastern Division solvents department, New York, becomes district manager at St. Louis. **A. P. Howe**, senior technical salesman at Chicago, goes to San Francisco as Western Division chemical products manager. **William Q. Mooney** has become manager of marketing's new employee development department and **W. E. Keegan**, formerly assistant to Mr. Steck, has become assistant to the sales manager of Shell Chemical's Eastern division.

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You can improve performance as well as cut costs by using coatings based on one of the many BAKELITE or VINYLITE Resins. Write Dept. QF-69 for folder giving case histories of severe coating applications.

Photo shows milk plant equipment made by Cherry-Burrell Corporation, Chicago 6, Ill., and coated with VINYLITE Resin coatings in Cherry-Burrell Blue. Coatings were prepared by Stoner-Mudge, Inc., Pittsburgh 33, Pa.

## Case Histories Prove Performance

**BAKELITE Resin Floor Varnish**—Floor finishes based on BAKELITE Resins provide extreme wear resistance that minimizes maintenance costs. A typical case history has been the gymnasium floor of the Sewickley (Pa.) High School—subject to rough daily service from basketball and other events—even school dances. Yet, four years after being coated with an air-drying varnish based on BAKELITE Resin, it still maintained its lustrous surface. No touch-up had been needed, either. And, the stripes and markings applied before the BAKELITE Resin coating were just as sharp and new-looking as when applied.

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—Very few industrial coating problems are identical. Minute changes in formulations can make a tremendous difference in satisfaction. Coatings for water purification units are an excellent example. Here, a specially-formulated BAKELITE Resin baking system provided not only the protection normally required for metal equipment, but also protected pipes and tanks against electrical leakage and the corrosive action of ozone.

### VINYLITE Resin Coatings for Railway Equipment

—Normal service conditions are tough enough on industrial coatings! Add the problems that railroad freight cars bring . . . vibration, weather variations, pounding with sledge hammers to loosen loads . . . and it takes top performance for a coating to stand up. Despite this rough and tough treatment, freight cars of the Illinois Central Railroad, protected with VINYLITE Resin coatings, took this treatment plus rain, heat, cold, sun, corrosive loads and fumes for over six years—and the coatings were still in good condition!

### Structural Finishes for Corrosion-Erosion Resistance

—Another example of how well BAKELITE Resins solve difficult coating problems was the painting of structural steel work on river locks and dams in the Monongahela River. Acid pollution and flow of silt had developed a serious combination of costly corrosion and erosion. Reports stated "ordinary paints are of little value in preventing corrosion and erosion under the conditions described." After seven years' research and testing, the engineers in charge determined that pigmented BAKELITE phenolic resin coatings were superior to any other for this use.

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# Corrosion Abstracts

## Index to CORROSION ABSTRACTS

Vol. 9      October, 1953      No. 10

	Page
<b>1. GENERAL</b>	
1.7 Organized Studies of Corrosion	207a
<b>2. TESTING</b>	
2.3 Laboratory Methods and Tests	207a
2.4 Instrumentation	209a
<b>3. CHARACTERISTIC CORROSION PHENOMENA</b>	
3.2 Forms	210a
3.3 Biological Effects	210a
3.4 Chemical Effects	210a
3.5 Physical and Mechanical Effects	210a
<b>5. PREVENTIVE MEASURES</b>	
5.3 Metallic Coatings	211a
5.4 Non-Metallic Coatings and Paints	211a
5.5 Oil and Grease Coatings	216a
5.7 Treatment of Medium	216a
5.8 Inhibitors and Passivators	216a
5.9 Surface Treatment	218a
5.11 Design-Influence on Corrosion	224a
<b>6. MATERIALS OF CONSTRUCTION</b>	
6.2 Ferrous Metals and Alloys	224a
6.3 Non-ferrous Metals and Alloys—Heavy	228a
6.4 Non-ferrous Metals and Alloys—Light	230a
6.5 Metals—Multiple or Combined	233a
6.6 Non-Metallic Materials	233a
6.7 Duplex Materials	234a
<b>7. EQUIPMENT</b>	
7.1 Engines, Bearings, and Turbines	236a
7.2 Valves, Pipes and Meters	236a
7.3 Pumps, Compressors, Propellers, and Impellers	236a
7.5 Containers	236a
7.7 Electrical, Telephone and Radio	237a
<b>8. INDUSTRIES</b>	
8.1 Group 1	238a
8.2 Group 2	238a
8.3 Group 3	238a
8.4 Group 4	238a
8.5 Group 5	240a
8.7 Group 7	240a
8.8 Group 8	240a
8.9 Group 9	242a

## 1. GENERAL

### 1.7 Organized Studies of Corrosion

#### 1.7.1, 5.2.1

Cooperative Corrosion Protection Benefits Miami Utilities. D. T. ROSSELLE. *Corrosion*, 9, No. 6, 1 (News Section) (1953) June.

Through the Greater Miami Corrosion Control Committee, the principal operators of underground utility plants in the Miami, Florida area cooperatively protect their plants. The telephone company, gas company, and water utility contribute to joint operation of a cathodic protection system and cooperate in electrolysis surveys. 4898

## 2. TESTING

### 2.3 Laboratory Methods and Tests

#### 2.3.2, 2.2.2, 5.4.5, 2.3.7

New Laboratory for Durability Studies of Protective Coatings. *Org. Finishing*, 12, No. 5, 16-17 (1951) May.

A special laboratory, designed and constructed by the Building Technology Division of the National Bureau of Standards, was developed primarily for studying organic coating materials, such as, asphalts, tars, and paints, to meet the requirements of most materials exposed to weathering. An actual weathering ex-

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AWWA—Journal, American Water Works Association, Amer. Water Works Assoc., 521 Fifth Ave., New York 17, N. Y.  
BL—Current Technical Literature, Bell Telephone Laboratories, Inc., Murray Hill, N. J.  
BTR—Battelle Technical Review, Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio.  
BNF—Bulletin; British Non-Ferrous Metals Research Association, 81-91 Euston St., London NW 1, England.  
CALCO—Calco Chemical Division, American Cyanamid Corp., Bound Brook, New Jersey.  
CE—Chemical Engineering, McGraw Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.  
CEC—Consolidated Edison Co. of New York, Inc. 4 Irving Place, New York 3, New York.  
EL—Electroplating, 83/85 Udney Park Road, Teddington, Middlesex, England.  
EW—Electrical World, McGraw-Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.  
GPC—General Petroleum Corp. of California, 2525 East 37th St., Los Angeles 11, Calif.  
INCO—The International Nickel Co., Inc. 67 Wall Street, New York 5, New York.  
IP—Institute of Petroleum, 26 Portland Place, London W#1, England.  
JSPS—Japan Society for the Promotion of Science, Address: Mr. Hayata Shigeno, Secretary, Committee of Preventing Corrosion, c/o Government Chemical Industrial Research Institute, 1-Chrome Nakameguro, Meguro-ku, Tokyo, Japan.

MA—Metallurgical Abstracts, Institute of Metals, London, England, 4 Grosvenor Gardens, London SW 1, England.  
MI—Metallurgia Italiana, Associazione Italiana di Metallurgia, Via S. Paola, 10, Milano, Italia.  
MR—Metals Review, American Society of Metals, 7301 Euclid Ave., Cleveland 3, Ohio.  
NALCO—National Aluminate Corp. 6216 West 66th Place, Chicago 38, Illinois.  
NBS—National Bureau of Standards, Supt. of Documents, U. S. Gov't Printing Office, Washington 25, D. C.  
NSA—Nuclear Science Abstracts, United States Atomic Energy Commission, Technical Information Division, Oak Ridge, Tenn.  
PDA—Prevention Deterioration Abstracts, National Research Council, 2101 Constitution Ave., Washington 25, D. C.  
RA—Refrigeration Abstracts, American Society of Refrigeration Engineers, 40 West 40th St., New York 18, N. Y.  
RM—Revue de Metallurgie, Paris, France, 5 Cite Pigalle, Paris (9e), France.  
RPI—Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries, Research Association of British Paint, Colour & Varnish Manufacturers, London, Waldegrave Rd., Teddington, Middlesex.  
SE—Stahl und Eisen, Verlag Stahlisen, M. B. H., Dusseldorf, August-Thyssen Str. 1. Postcheck Kohn 4110, (22a) Dusseldorf, Germany.  
TIME—Transactions of Institute of Marine Engineers, 85 The Minories, London EC 3, England.  
UOP—Universal Oil Products, 310 South Michigan Ave., Chicago, Illinois.  
ZDA—Zinc Development Association, Lincoln House, Turl Street, Oxford, England.

posure deck has also been constructed on the roof of the laboratory where identical materials are thus exposed concurrently in the controlled lab and on the roof. Data from these studies should provide some statistical correlation between outdoor weathering in the Washington, D. C., area and in accelerated durability testing in each of the several types of machines.—INCO. 4819

### 2.3.2, 5.4.5

**The Vila Method for Short Period Testing of Antirust Coatings Compared with the Salt Spray and the Tropical Cabinet Methods.** S. KOHLER AND K. LAURELL. Statens Provingsanstalt, Report No. 106, 1949 (In Swedish); *J. Iron and Steel Inst.*, 168, Part 4, 432-433 (1951) Aug.

The protective value of four paint schemes on steel plates was assessed and compared using the Vila short-time corrosion testing apparatus. This test appears to be effective in grading paints of one type, but the salt-spray test, which is much cheaper, is more suitable for comparing paints of different types. Paint coatings easily affected by water can be tested in a reasonably short time in a "tropical cabinet" but it would take a very long time to test more permanent paints in this way.—INCO. 4738

### 2.3.2, 5.4.5, 2.2.2

**Durability Testing.** H. RABATE. *Peintures pigments vernis*, 27, No. 7, 417-424 (1951).

Conclusions reached by various testing authorities on the effectiveness of accelerated testing (in particular weathering) techniques are reviewed. Accelerated weathering is not an exact method for determining the probable durability of good-class paints. It will never be possible to reproduce exactly the variations of conditions encountered in natural weathering or the same modes of breakdown. Accelerated techniques are inferior to statistically interpreted natural weathering results, but are useful for comparison of materials of similar composition.—RPI. 4936

### 2.3.2, 5.4.8

**Accelerated Testing for Anti-Fouling Paints.** M. RAGG. *Farbe u. Lack*, 57, No. 4, 139-149 (1951).

The paper presents two accelerated sea-water leaching tests for anti-fouling compositions. The plate under test is either continuously sprayed with sea-water for a certain period, the spraying device and centrifugal pump being made of glass, or the plate is rotated in water. The water is tested subsequently for copper and mercury with organic reagents such as diethyl dithiocarbamate and dithione. A detailed description of the apparatus, procedure and evaluation is given.—RPI. 4934

### 2.3.2, 5.9.1

**Cleaning and Preparation of Metals for Electroplating—Degreasing Evaluation Tests: Sequential Testing.** H. B. LINFORD AND E. B. SAUBESTRE. *Plating*, 38, Nos. 8, 11, 12; 847-855, 1157-1160, 1263-1266 (1951) Aug., Nov., Dec.; *Ibid.*, 39, No. 1, 55-63 (1952) Jan.

Object of this phase of the project was to compare the performance of various degreasing-evaluation tests and to obtain a measure of their sensitivities by means of sequential testing. In this type of testing, a panel is consecutively ex-

amined by a series of tests. Several testing series are required. The relative sensitivity of the tests in detecting residual soil after alkaline cleaning is as follows: atomizer > fluorescent dye > spray pattern (water-break) > potassium ferrocyanide paper > copper sulfate dip. Results of tests are discussed. Tables and 11 references are given.—INCO. 4775

### 2.3.4

**New Reagent Papers for Testing Porosity and for Identifying Metals.** A. KUTZELNIGG. *Metalloberfläche*, 3, No. 8, B113 (1951).

Various reagent papers have been produced for the testing of porosity and for identifying metals. Paper impregnated with dimethyl glyoxime, when moistened with water, reacts with metallic nickel in a few minutes. A test paper of dithione, moistened with an organic solvent, gives a raspberry red color with zinc and an orange color with cadmium. Zinc and magnesium are detected by their power to reduce dyestuffs. Neutral-red paper, moistened with water, becomes yellow in a few seconds in contact with magnesium metal. Methylene blue paper, moistened with dilute hydrochloric acid, is bleached by zinc. Eriochromcyanine paper develops bright reddish-purple spots in contact with aluminum. The use of these test papers requires no special knowledge or skill, and does not consume any metal. Test papers can be used to detect and check anode reversal and its undesirable consequences; another use is in the sorting of mixed scrap metal.

The porosity of nickel plating on iron has been tested hitherto almost exclusively by ferroxy (a solution of potassium ferricyanide and sodium chloride). The ferricyanide reacts with divalent iron in solution to give Turnbull's blue; the presence of a salt which has a slight corrosive action on iron is necessary in order to bring the iron into solution. The solution also attacks nickel and blue spots are formed which interfere with the iron reaction, so that the test is not satisfactory. A test paper impregnated with  $\alpha$ -nitroso- $\beta$ -naphthol (Porotest I) gives better results, using an organic solvent. A bluish-green color is obtained with ferrous iron. The presence of pores in a nickel or tin deposit is shown in five minutes by the formation of bluish-black spots. The nickel deposit is scarcely attacked. Corrosion tests on nickel, iron and tin plated strips suspended in ferroxy and in  $\alpha$ -nitroso- $\beta$ -naphthol confirm these results.

The porosity of silver deposits can be investigated with dimethylglyoxime paper using nickel as an undercoat. The porosity of silver deposits on brass and copper can be investigated with a haematoxylin test paper (Porotest II); this paper can also be used for copper or brass deposits on iron.—EL. 4787

### 2.3.5, 2.4.2

**Rotogenerative Detection of Corrosion Currents.** JOSEPH B. MCANDREW, WILLIAM H. COLNER, AND HOWARD T. FRANCIS. Armour Research Foundation, Chicago. U. S. National Advisory Committee for Aeronautics, Technical Note No. 2523, November 1951. 12 p.

A new rotogenerative technique for studying corrosion phenomena is described. The method permits the detection and location of galvanic currents produced by local corrosion cells. For the investigation of stress-corrosion, a hollow cylindrical specimen is rotated

at several hundred revolutions per minute in the corrosion medium. Internal hydraulic oil pressure provides the desired stress level in the walls of the rotating specimen. A small reference electrode is positioned as near the specimen as possible to scan the surface of the metal. The signal produced is amplified and applied, together with a suitably synchronized sweep voltage, to an oscilloscope. The resulting standing pattern produced on the oscilloscope screen is a reproduction of the potential fields set up in the corrosion medium by the currents flowing between the elements of local cells. No appreciable drag effect exists at the rotational speeds used.

With this method, the corroding potential need not be constant; a gradual drift of the specimen's d-c potential will not be detected by the amplifier system. The a-c signal, however, is passed readily by the condenser when rotational speeds of several hundred revolutions per minute are used.

The rotogenerative technique can be used with electrolytes varying widely in conductivity and is applicable to systems whose local cells possess small physical dimensions. The principal value of this method lies in its ability to detect corrosion currents, provided they produce a potential field around the tip of the electrode, even when the precise location of anodic and cathodic areas is not known beforehand. This method may be of value not only in studying stress corrosion but in investigating inhibitor action, cathodic protection, and electrodeposition.—PDA. 4784

### 2.3.5, 2.4.2, 5.4.5

**Apparatus for the Rapid Measurement of State of Preservation of a Painted Metal Surface In Situ.** G. MANTOVANI. *Pittura e vernici*, 7, No. 8, 31-35 (1951).

An illustrated account is given of a portable apparatus for the measurement of current flow across a paint film protecting a metal surface, under standard conditions. From the values and their change with time, conclusions can be reached on the efficiency of the film as a corrosion-resistant barrier.—RPI. 4839

### 2.3.5, 5.4.5

**Electrochemical Measurements with Paint Films on Metal.** A. NASINI AND G. OSTACOLI. *Ind. della Vernice*, 5, No. 52, 148-151 (1951).

The use of current-time and potential-time curves of metal electrode/paint/electrolyte solution/standard electrode systems for evaluating the corrosion resistance of the paint is discussed. Where the metal is readily corroded, the presence of insoluble corrosion products renders the results of equivocal value. It is therefore proposed to use a noble metal electrode in a solution of the metal salt, and experimental results for a silver electrode in a silver nitrate solution are presented, the coating systems being an alkyl resin and plasticized and unplasticized ethyl cellulose. Potential/time curves for the systems are presented and discussed.—RPI. 4791

### 2.3.6, 2.3.2, 2.3.9

**The Spectrographic Analysis of Surface Films Used for the Protection of Metallic Alloys: Application to Chromized Layers.** F. MALAMAND. *Recherche aeronaut.*, No. 22, 27-31 (1951).

A method is described for the spectrographic analysis and investigation of chromium diffusion layers on iron and

steel surfaces such as are produced by chromizing. The accuracy of the method for the analysis of iron-chromium alloys containing 10-50% chromium is demonstrated, and it is claimed that by controlled successive electropolishing treatments in an aceticperchloric acid electrolyte followed by spectrographic analysis, the chromium penetration can be determined at 0.005 mm. intervals of depth. Chromium penetration curves obtained by using this technique on iron containing 0.014% carbon and steels containing 0.1, 0.4, and 1.2% carbon are presented and discussed. 15 references.—MA. 4855

### 23.6, 3.6.4, 3.4.6

**Investigation of Oxidation and Corrosion Processes on Metal Surfaces by the Measurement of Contact Potentials.** H. NEUBERT AND H. HANSEL. *Z. angew. Phys.*, **2**, 319-323 (1950); *Physics Abs.*, **54**, 116 (1951).

The time-variation of contact potentials was measured by Kelvin's method for aluminum, zinc, iron, lead, and Duralumin, and characteristic variations were found. In this way the corrosion and oxidation of metals in gases and vapors were investigated, and a logarithmic law of oxide growth was confirmed.—MA. 4791

### 23.6, 3.7.1

**Phase-Contrast Metallography.** E. C. W. PERRYMAN. *Metallurgia* (England), **44**, No. 262, 97-102 (1951) Aug.

The phase-contrast microscope is described and its metallurgical application discussed. Examples are given showing the sensitivity of this microscope in revealing small differences in surface level. The microscope is used for two main purposes—a. revealing more detail in a structure and b. help in interpretation of structures seen under normal illumination. In the first instance, light and dark lamellae parallel to the rolling direction were noted in a heat-treated aluminum-magnesium alloy. The possibility exists that these lamellae were due to uneven etching caused by an uneven concentration of magnesium across the section of the rolled sheet. This would not have been noticed in normal illumination. Striations in cold worked material can be revealed by use of the phase-contrast microscope. Structures containing two or more phases are often found where there is little contrast between the second phase and the matrix. Viewed in the phase contrast microscope, increased contrast is obtained, making the second phase particles easily visible. Owing to interpretation difficulties, the microscope will not find much use in the routine examination of metallic specimens.—ALL. 4835

### 23.6, 3.7.1

**Recent Developments in Metallography.** E. C. W. PERRYMAN. *Metal Industry* (England), **79**, Nos. 2,3,4 and 5; 23-26, 51-53, 71-73, 111-113, 131-133 (1951) July 13, 20, 27, Aug. 10.

This is an outline of the advances which have been made in the two fields of specimen preparation and apparatus in metallographic technique. These include phase contrast microscopy, the reflecting microscope, use of polarized light, and microhardness testing. Specimen preparation is done by taper sectioning, and usually mounting on bakelite. In mechanical polishing the use of lead laps and diamond dust for polishing specimens has been advocated. The reflecting microscope has two advantages

over the normal microscope: a greater working distance and the fact that it is achromatic. Polarized light reveals grain structure, detects preferred orientation and serves for an examination of oxide coating. It is used in detection of internal strains and plastic deformation, identification of phases in multiphase structures and identification of non-metallic inclusions. The electronmicroscope has three advantages over the light microscope: increased resolving power; greater depth of focus and ability to give information regarding the surface topography; the only disadvantage being that a replica technique has to be used. Micro-hardness testing is used for testing of thin metal foil and very fine wire, determination of the hardness of electrodeposited coatings and studying diffusion and age-hardening techniques.—ALL. 4859

### 2.3.7

**Color Effects in Electrographic Printing.** MAX KRONSTEIN. *Paint and Varnish Production*, **41**, No. 9, 19-21, 36 (1951) Sept.

Describes the development of the above so it can be utilized as a test method for paint on metals. It also allows a new approach to the study of corrosion. Tests made of coatings over base and phosphate-treated steels are given. Microphotos.—BLR. 4884

### 2.3.7, 5.4.5., 2.2.5, 2.3.2

**Rate of Erosion, Hardness and Abrasion Resistance of Drying Oil Films.** E. B. KISER AND J. H. COULLIETTE. *Paint, Oil & Chem. Rev.*, **114**, 10, 12-14, 38, 40, 42-43 (1951) Nov. 22.

Describes testing procedure and results of tests on pure paint vehicles and pigmented compounds prepared for the testing program of the Federation of Paint and Varnish Production Clubs. Data are charted.—BLR. 4748

### 2.3.9, 2.4.3

**The Detection of Internal Faults with the Help of Ultrasonic Images.** R. POHLMAN. *Metallurg. Corrosion Industries*, **26**, No. 314, 410-414 (1951).

An account is given of the method of ultrasonic examination of "transluminous" metal objects by irradiation with an ultrasonic beam focused by sonic lenses. The image is rendered visible by a special transparent cell containing a light oil in which reflective platelets of aluminum are suspended. These are oriented || the wave fronts when traversed by the beam, and thus on illumination from outside the cell form a visible image of the "transluminous" object. Advantages and limitations of the method are discussed.—MA. 4888

### 2.3.9, 2.4.3, 8.8.5

**Xeroradiography Can Cut X-Ray Inspection Costs.** M. D. PHILLIPS AND S. A. WENK. *Battelle Memorial Institute. Iron Age*, **168**, No. 22, 86-89 (1951) Nov. 29.

When the metal working industry swings into defense production, the use of industrial radiography as a nondestructive test increases tremendously. Radiographic inspection is insurance against service failures, or malfunctioning of vital equipment. Xeroradiography, a novel form of radiography, developed by Battelle Memorial Institute, offers several advantages over conventional radiographic inspection methods. The process is essentially physical. It is a dry process. No wet processing or

chemical solutions are required to develop the X-ray images. Dry pigments may be used to reveal the image after X-ray exposure. Certain materials, such as one form of selenium, are normally good insulators. When irradiated with X-rays, however, they become relatively good conductors of electricity. This response to X radiation is the basis of xeroradiography. Plates are used repeatedly and are not spoiled by accidental exposure to light, X-rays, or nuclear radiation. The image may be quickly developed by a simple method and transferred to another surface, as of paper, on which it is fixed to produce a permanent record. Initial tests showed that, with proper exposure, contrast sensitivities of 2% could be obtained throughout a wide range of materials and thicknesses. 4867

### 2.3.9, 3.2.3, 3.8.4

**An Electron-Diffraction Study of the Structure of Long-Chain Polar Compounds on Metal Surfaces.** JOHN VEYSEY SANDERS. *Abstr. Dissert. Univ. Cambridge*, 1949, 1950, 1951, 204-205.

The orientation of monolayers of long-chain aliphatic acids on metal surfaces was studied by electron-diffraction methods. Changes of orientation were produced by heating the metals. Disorientation temperature  $\Theta$ , at which the absorbed monolayer lost its preferred orientation were determined. For fatty acids,  $\Theta$  depends upon the metal substrate, and the method of preparation of the monolayer. Anomalous results on the lubrication of metals by esters are due to a little free acid formed by hydrolysis.  $\Theta$  is near the melting point of the bulk material of which the monolayer is composed, and corresponds well with the temperature at which boundary lubrication fails.—MA. 4942

## 2.4 Instrumentation

### 2.4.2, 2.3.7

**Paint Coating Thickness Meters. Part I and II.** R. QUARENDON. *Paint Manufacture*, **21**, 357-362 (1951) Oct.; *ibid.*, **22**, 5-9, 30 (1952) Jan.

Reviews types of meter currently available for measurement of the thickness of paint films on various bases. Describes the principles on which these instruments are designed and their fields of usefulness, discusses their advantages and limitations, and deals briefly with problems encountered in this field and progress towards their solution.

Part II deals with penetrometers, wet-film thickness gages, electrical capacity, and radiation-thickness meters.—BLR. 4912

### 2.4.3, 6.5

**Experiences in the Routine Non-Destructive Testing of Metals.** (In German) H. MAYER. *Metall.*, **5**, Nos. 15/16, 331-334 (1951) Aug.

Experience obtained during 1942-1945 in routine examination of aluminum, copper and zinc alloys with the Durokawimeter and other instruments (based on electro-magnetic induction) developed by Dr. Forster.—BNF. 4921

### 2.4.3, 2.3.9

**Theoretical and Practical Sensitivity Limits in Fluoroscopy.** D. T. O'CONNOR AND D. POLANSKY. *Non-Destructive Testing*, **10**, No. 2, 10-21 (1951).

The factors controlling sensitivity of



flaw detection in fluoroscopy are discussed in detail, with particular reference to the theoretical aspects. Graphs and tables show: 1. the minimum defect discernibility for different image magnifications, 2. the brightness of various fluoroscopic screens for two kilovoltages, 3. the relation between screen brightness and kilovoltage, 4. values of image unsharpness for these same fluoroscopic screens, 5. the resistance of X-ray barrier windows of lead glass to discoloration, 6. the relative X-ray absorptions for lead glass and liquid X-ray barriers, 7. penetrometer sensitivities obtainable in the fluoroscopic inspection of magnesium and aluminum, 8. the minimum observable defect size as a function of contrast, and 9. the relation between minimum size of observable defect, focal spot size, and screen brightness. The optimum screen brightness level is 1.0 millilambert, which is 100-10,000 times brighter than that normally used. Other desirable features in fluoroscopic equipment are stated. It is claimed that with these features, which include a rotating-anode tube (intended for intermittent service), penetrometer sensitivities obtainable for aluminum and magnesium alloys are up to four times superior to those obtained with normal equipment intended for industrial fluoroscopy. 49 references.—MA. 4877

### 3. CHARACTERISTIC CORROSION PHENOMENA

#### 3.2 Forms

##### 3.2.2, 1.7.2.

**Climatic Testing for Export Finishes.** *Product Finishing* (London), 4, No. 4, 64-69 (1951).

The climate of south-west Florida and the facilities available for exposure testing at Miami are discussed. Such testing gives a rapid indication of performance under tropical conditions.—RPI. 4906

##### 3.2.2, 5.4.2, 3.5.9

**Ceramic Coatings for Prevention of Carbon Adsorption in Four Heat-Resistant Alloys.** JOSEPH W. PITTS AND DWIGHT G. MOORE. National Advisory Committee for Aeronautics, Technical Note 2572, Dec. 1951, 14 pages.

Three ceramic coatings were applied to Inconel and three 18-8 type stainless steels and then tested for their effectiveness in preventing carbon adsorption under strongly carburizing conditions, that is, box carburizing. At 1350° F. no carbon pickup occurred after the 4-hr. treatment but, at 1500° and 1650° F., carbide precipitation was evident in the uncoated stabilized 18-8 steels extending down from the surface to a depth as great as 0.007 in. In most cases the ceramic coatings completely prevented the adsorption. Tables, graphs, and photomicrographs. 11 references.—BLR. 4866

##### 3.2.3, 5.7.4

**Making Metal Powders Moisture-Repellent as Protection Against Corrosion.** A. I. LEVIN AND A. V. POMOSOV. *Doklady Akad. Nauk S.S.S.R.* 72, 1075-1078 (1950); *Chem. Zentr.*, I, No. 23, 3257-3258 (1951); *Bibliog. of Ind. Diamond Applications*, 8, 590 (1951).

An important problem in powder metallurgy is the protection of powder against corrosion by contained moisture.

An attempt is made to solve this by forming a moisture-repellent film on the particles through addition of stabilizers to the wash medium after electrolysis, e.g., compounds containing aliphatic and aromatic groups, oleic and anthranilic acids, sodium oleate and other soaps, thiocresol, Vaseline solution, etc. Copper powder from the electrolysis of acid copper sulfate solution was washed with distilled water containing various stabilizing additions and dried. Water repellency was determined by the degree of wettability in water, or acid or alkaline solutions, and the stabilizing effect by corrosion tests after 24-hr. treatment in a carbon dioxide stream saturated with water vapor. Good results are recorded. In some cases after treating with soap solutions, corrosion resistance increased 50 to 70 times, and no change in appearance occurred on storing for twelve months. Optimum addition of such stabilizer is important, as is the dispersing effect in breaking up agglomerates of powder. The finer the powder, the more marked is the effect.—RPI. 4785

#### 3.3 Biological Effects

##### 3.3.3, 6.6.11, 1.6

**Proceedings Wrightsville Beach Marine Conference.** 59 pp. 1951. National Academy of Science—National Research Council, Washington, D. C.

Symposium primarily on the marine-borer problem in relation to wood deterioration, with one paper on concrete piles and their protection. Tables diagrams, photographs, and references.—BTR. 4798

##### 3.3.4, 7.4.2, 6.3.6, 6.2.1

**Bacterial Corrosion of Construction Materials.** C. D. PARKER. *Commonwealth Engr.*, 39, No. 5, 190-196 (1951).

Causes of bacterial corrosion and the mechanism of attack are discussed. Corrosion of horizontal brass condenser tubes at a power-house was due to a species of bacteria known as "Proteus," which produces ammonia from organic matter. On shut-down some sea-water polluted with organic matter was left stagnant in the pipes, and the ammonia produced accelerated corrosion. Examples of attack of ferrous materials are also described.—MA. 4833

##### 3.3.4, 8.3.5, 5.4.8

**Cause and Cure of Fungi.** A. MINICH. *Can. Paint & Varnish Mag.*, 25, No. 6, 24+ (1951).

Moisture is the main factor favoring mildew development. For painting food plants, such as dairies, a combination of an antiseptic wash and a fungicidal paint is advocated.—RPI. 4946

##### 3.3.4, 8.9.5, 4.6.11

**Ship Corrosion Due to Bacterial Action.** W. S. PATTERSON. *Trans. North East Coast Inst. Engrs. & Shipbuilders*, 68, No. 2, 93-106 (1951) Dec., discussion, *ibid.*, 68, No. 4, D23-D32 (1952) Feb.; *J. Brit. Shipbuilding Res. Assoc.*, 7, No. 1, 67-68 (1952).

Bacterial corrosion due to sulphate-reducing bacteria occurs essentially under anaerobic conditions, i.e. in the absence of oxygen. The corrosion product is not rust but contains black sulphide of iron. It is somewhat paradoxical to find corrosion of a most severe character occurring in an environment from which oxygen

is virtually excluded. In the case of the ship corrosion which forms the basis of this paper, such anaerobic conditions would be attained due to the fact that the hull of the vessel below the water line was encased for several weeks in a thick deposit of mud which is attributable to the location of the vessel and its movement while it rested on the mud bank and to the flow of water carrying suspended mud. This coating of mud was likely to be attached most easily to projecting surfaces on the plates and on rivet points and in view of its viscous and adhesive nature would exclude oxygen from the encased metal surfaces. The explanation of metallic corrosion under anaerobic conditions is to be found in the activity of certain micro-organisms. These are the sulphate-reducing bacteria which are found in almost every type of soil and natural water. These organisms frequently cause the destruction of buried steel and iron water-pipes and their activities are now well known to water engineers. Much work has been carried out to investigate the corrosion of such pipes by this agency, both in this country and in America. The result of this type of attack on water pipes has been severe pitting, frequently perforation, and always a blackening of the clay soil environment. The work of Verillon in France indicates that the same organisms are responsible for certain types of marine corrosion. They possess the destructive property of removing oxygen from sulphates and for their development they require a medium containing in addition to sulphates, organic matter, moisture, and in some cases iron salts. All of these constituents are present in the mud banks of most marine estuaries. Laboratory experiments by Bunker have shown that sulphate-reducing bacteria can be active in very restricted areas of oxygen deficiency in close proximity to regions of abundant oxygen supply. This condition would pertain in the mud encasements on the hull of a vessel which was immersed in aerated tidal river water and which was in contact with mud banks for some period each twenty-four hours. Thus corrosion due to sulphate-reducing bacteria requires that the environment shall be anaerobic or nearly so, and it results in severe local pitting, the formation of black corrosion products, and an accompanying reduction of sulphate to sulphide in the corrosion environment.—TIME. 4873

#### 3.4 Chemical Effects

##### 3.4.6, 6.5

**The Oxidation of Metals in an Artificial Atmosphere.** (In Dutch). C. H. LUITEN. *Smit Mededelingen*, 6, 122-126 (1951) Oct.-Dec.

Shows that oxidation of metals in a controlled atmosphere will take place if the dissociation pressure of the metal-oxide is smaller than the oxygen pressure of the surrounding atmosphere. Also, in so-called oxygen free atmospheres, a certain amount of oxygen exists which may be calculated from the equilibrium data of the dissociation of carbon dioxide or water. The oxygen pressure appears to depend on and to vary with the square of the carbon dioxide-carbon monoxide or water-hydrogen ratios. Therefore, in an atmosphere containing carbon dioxide, carbon monoxide, water, and hydrogen, these ratios are not independent. Some practical conclusions are given.—BTR. 4755

### 5.3 Physical and Mechanical Effects

5.3.4, 4.7

Some Problems Encountered in the Use of Soluble Oils. A. W. LINDERT. *Lubrication Eng.*, 7, 223-227 (1951) Oct.

"Soluble" or "emulsifiable" oils are used in many metal-working processes, especially grinding, as coolants, to avoid localized burnings, and to prevent undesirable changes in surface properties. However, bluish-black spots frequently develop. This phenomenon was studied and a mechanism postulated to explain it. Data are tabulated and charted.—BLR. 4776

5.3.8, 2.3.7

The Question of Corrosion Fatigue. (In Russian.) G. V. KARPENKO. *Doklady Akad. Nauk SSSR*, new ser., 79, 287-288 (1951) July 11.

Rotating-beam fatigue tests were made on steel specimens under various conditions of corrosion. Charted data and typical results.—MR. 4732

5.3.9, 3.2.3, 3.7.2, 5.3.2, 5.4.2

The Surface Protection of High-Melting-Point Metals. R. KIEFFER AND E. NACHTIGALL. *Heraeus Festschrift*, 1951, 186-205.

Since tungsten and molybdenum were introduced, in the ductile form, into high-temperature technology some 40 years ago, numerous attempts have been made to improve the heat-resisting properties of these metals in two ways, viz. 1. by alloying the metals with beryllium, boron, silicon, titanium, zirconium, aluminum, thorium, chromium, cobalt, or nickel and 2. by coating the metals with high-m.p. oxides, oxide mixtures, or non-oxidizable metals. Methods proposed for alloying, embedding in ceramic materials, and various methods of producing the protecting sheath, including deposition from the gas phase, are briefly described. 40 references.—MA. 4747

5.3.8, 5.9.4, 6.4.1

Stress Corrosion. *Engineers' Digest*, 12, 239 (1951) Aug.

The outstanding feature of stress corrosion is that while the amount of metal actually corroded may be small, the damage is quite out of proportion. Unlike corrosion fatigue, the occurrence of stress corrosion is conditional upon the existence of zones of weakness in the metal, and more often than not these zones are intergranular in character. Stress corrosion may be caused by residual stresses, or by constraint, or it may be due to stresses arising from service conditions; and any of them may be additive. Tensile service stresses or alternating service stresses should be kept within the safe limit. By introducing compressional stresses by peening into the surface of the material, the harmful effect of service stresses of tensile nature may be counteracted. Compressional surface stresses may also be produced by nitriding. Surface treatment has been advocated for light alloys. If this is applied by means of abrasion, care must be taken that the direction of abrasion is parallel to that of the service stress, otherwise the grooves will act as stress raisers. Aluminum-magnesium alloys should not be surface-treated prior to ageing, since this would favor the changes responsible for intergranular

susceptibility. Surface treatment after ageing is less dangerous. Expert opinion is that even very slight unintentional surface treatment may suffice to set up corrosion cracking, which, once started, may penetrate through a large cross section. This warning applies, in particular, to solution-treated material and not so much to commercial material which has received the customary heat treatment.—TIME.

3.5.9, 6.5

A Comparison Between Fe-Cr-Al and Ni-Cr Alloys for High Temperature Service. G. HILDEBRAND. Paper before 1st World Metallurgical Congr., Detroit, Oct., 1951. Proc. 1st World Metallurgical Congr., ASM, 1951, 632-636.

Comparison of iron-chromium-aluminum, Kanthal, and 80-20 nickel-chromium alloy for use as electrical resistance materials. Iron-chromium-aluminum alloys constitute an excellent substitute for nickel-chromium since their properties make them, in many cases, superior to nickel-chromium alloys. Iron-chromium-aluminum materials can be used up to 1350° C., whereas the maximum working temperature of the best nickel-chromium is 1150° C. Both the life and electrical properties, as well as the mechanical properties at room temperature, are better for the iron-chromium-aluminum type, while from corrosion and heat resisting points of view the nickel-chromium material has the advantage.—INCO.

## 5. PREVENTIVE MEASURES

### 5.3 Metallic Coatings

5.3.4, 5.9.1, 8.9.1, 1.2.4

Surface Treatment and Plating in Naval Aircraft. G. S. MUSTIN. *Metal Finishing*, 50, No. 2, 53-61+ (1952) Feb.

The author summarizes the hazards to which U. S. naval aircraft are subjected by climatic conditions, operations, operational materials, and constructional factors, and then discusses the cleaning, surface treatment and plating of the component parts of such aircraft. The specifications to be followed for each operation are listed and some of the background information leading to these requirements is reviewed. The most commonly used treatments on steel are cadmium and zinc plating, which are considered excellent not only because of their anodic protection of steel, but also because of their nearness to magnesium and aluminum in the electromotive series.—ZDA.

5.3.4, 7.6.9, 8.8.5

A Review of Factors Influencing the Life of Galvanizing Pots. D. N. FAGG. *Sheet Metal Inds.*, 28, No. 290, 574-575 (1951).

Fagg reviews the factors influencing pot life and concludes that the life depends on: 1) zinc temperature, 2) type of steel used for the pot, 3) fabricating defects in the pot, and 4) composition of zinc. He discusses these factors and shows that the life of a pot is governed by the observance of two main conditions: a) bath temp. must be below 480°C and b) the steel used must contain not greater than 0.07% silicon.—MA.

### 5.4 Non-Metallic Coatings and Paints

5.4.2, 1.6, 3.5.9

Radiation Suppressing Coatings for Metals at Elevated Temperatures. A. H. SULLY, E. A. BRANDES AND R. B. WATERHOUSE. 7 x 9 1/2 inches, paper, 24 pp. April, 1953. Fulmer Research Institute Ltd., Stoke Poges, Buckinghamshire, England. Per copy—15 shillings.

Tests were made to determine what coatings were best suited to reduce temperatures of metals subjected to radiated heat in gas turbines which must not be heated in excess of 800-900°C. Several ceramic coatings were tested to determine emissivity characteristics and various methods of bonding coatings were explored. Tests were made to determine the fatigue and thermal shock characteristics of the coatings, simulating service conditions. Results indicated certain coatings tested are capable of reflecting a high proportion of incident radiation and can stand a considerable amount of vibration and shock when applied correctly. They can be applied to Nimonic 75 and with a protective enamel undercoat to stainless and mild steel. Coatings of this type are not recommended for parts which normally operate over 600-900°C. Polished metals are excellent reflectors of radiation as long as polish remains. It is not indicated that the coatings will protect basis metal against attack by volatile constituents of the fuels, such as vanadium or lead compounds. 4752

5.4.2, 3.5.9

Recent Ceramic Coatings for High-Temperature Alloys. Nat'l. Bur. Standards, *Technical News Bull.*, 35, No. 10, 145-147 (1951) Oct.

Ceramic coatings recently developed by NBS are substantially increasing the service life of high-temperature alloys, particularly in the exhaust systems of aircraft. Most successful and widely used of these coatings is NBS ceramic coating A-417, which has been commercial production since early 1950. The coating is applied by spraying or dipping and is then fired for a few minutes at 1850°F. Ceramic coatings are applied to heat-resistant alloys for protection against such forms of deterioration as scaling and intergranular corrosion. The NBS coating A-417 is composed of a high-barium, alkali-free frit (glass) with a 30% admixture of chromic oxide. The preparation and application of A-417 are discussed. The value of A-417 has been established both by laboratory tests and by substantial service experience. Other coatings recently developed by NBS show promise for some applications.—TDD. 4793

5.4.2, 3.5.9, 7.4.1, 8.9.1

Ceramic Coatings for Metal Protection at High Temperatures. *Product Engineering*, 1951, 177-1-79, Nov.

There are two phases to the application of ceramic coatings to metals. One is the replacement of conventional but scarce high-temperature materials having large amounts of nickel, cobalt, columbium, and other high-cost elements with ceramic-coated low-alloy steel. The other equally important phase is the use of such coatings to extend the service life of these high-temperature alloys, which are in critically short supply.

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While work on the first of the above phases is still more or less in the experimental stage, considerable progress has been made on the second. For the future, ceramic coatings show promise for all types of heat exchangers, home heaters, locomotive and gas turbine components, combustion chamber liners, aircraft engine collector rings, and burner nozzles and jets, to name but a few potential applications. The function of ceramic coatings in aircraft applications is to protect the base metal from intergranular corrosion at temperatures that range from 1600° to 2100° F. Coatings to slow down the reaction must 1. have good resistance to high temperatures, 2. be able to withstand severe thermal stresses, and 3. possess good resistance to chemical attack. In addition, in heat exchanger uses, the coating should be thin and have good heat transfer properties so that performance of the unit is not impaired. Vitreous enamel coatings have good acid resistance, but are somewhat low in thermal shock characteristics. The South Wind Div. of Stewart Warner Corp. is using ceramic coatings for several types of aircraft heat exchangers that are an integral part of the aircraft exhaust system. So far as is known, this is the first large scale commercial use of such coatings. Various ceramic coatings are discussed.—TDD. 4872

### 5.4.2

Recent Developments in Ceramic Coatings for Steel. ALLEN G. GRAY. *Products Finishing*, 16, 44, 46+ (1951) Dec.

Discusses the above, as reported by various investigators. Some theories for adherence of porcelain enamels to steel are mentioned. Results of adherence and abrasion tests are given. Data are tabulated.—BLR.

### 5.4.2, 3.5.9, 6.5

The Growing Role of Protective Coatings for Metals in High Temperature Service. W. N. HARRISON (Nat. Bur. Standards.) Paper before ASTM, 53rd Ann. Mtg., Atlantic City, June 26, 1950. ASTM Sym. on Corrosion of Materials at Elevated Temperatures, Spec. Tech. Publ. No. 108, 1951, 114-121. See also: Ceramic Coatings Prevent Exhaust Gas Corrosion, *Iron Age*, 168, No. 10, 118 (1951) Sept. 6.

A ceramic coating used on an S.A.E. 1025 steel exhaust stack in gas turbines will effectively inhibit oxidation for long periods. It has been found possible to extend the life of molybdenum in air at 1650° F. to thousands of hours under conditions where it would burn up in minutes if unprotected. A ceramic coated 321 stainless steel sheet and uncoated specimens were given a pack carburizing treatment for three hours at 1650° F. Microscopic examination showed carbon penetration to 0.008 inch in the uncoated specimens, being precipitated as carbides in the grain boundaries but there was no indication of carbon infiltration in the coated specimen. Accelerated tests were made to determine if lead bromide vapor in air at high temperature has a tendency to corrode high-temperature alloys. Alloys tested were type 347 stainless steel, 19-9 DL, Inconel, Vitallium and Alloy S-816. The loss in thickness was 8 mils in 6 hours for type 347 steel, 6 mils for Inconel that had no pretreatment and 4 mils for Inconel that had been preoxidized. The same alloys with ceramic coatings had no significant loss in thickness. Graphs and illustrations.—INCO.

### 5.4.2, 6.3.15, 3.5.9

Development of a Protective Coating for Titanium Alloys; Six Months' Interim Technical Progress Report; May 19, 1951 Through November 30, 1951. STANLEY KLIZ AND RALPH WEHRMANN. *Fanstell Metallurgical Corp.* Dec. 26, 1951, 15 p.

The development of suitable coatings for the prevention of oxidation of titanium at elevated temperatures was investigated. A study was made of silicide coatings involving the preparation of compounds of titanium and silicon and the determination of their resistance to oxidation at high temperatures plus the accumulation of x-ray and metallographic data necessary in the examination and evaluation of coatings. Titanium silicides were synthesized by heating the powders of the elements. It was found that the oxidation resistance of TiSi<sub>2</sub> was outstanding. The material underwent no significant change during 1048 hours in air at 1000° C.—NSA. 4880

### 5.4.5

Characteristics and Application of Modern Coating Resins. W. H. PATRICK. *Paint Ind. Mag.*, 66, No. 11, 24-27+, No. 12, 9-10 (1951); *Official Digest*, No. 321, 615-628 (1951).

Some examples of the durability of alkyd resins in clear films and pigmented paints are given. Durability tests of clear films on steel, evaluated by rusting, show that alkyds are much superior to oleoresinous varnishes and that the superiority increases with phthalic anhydride content. Properties of alkyd resins are then discussed in relation to application conditions and problems.—RPI. 4852

### 5.4.5

Alkyd Resins in Anti-Corrosive Paints. M. LAMBERT. *Trav. peinture*, 6, No. 3, 63-65 (1951).

The possibilities of using alkyd resins as media for anti-corrosive paints are discussed in relation to the desired film properties, e.g., adhesion, impermeability to water, and durability. The results of a test to compare paints based on an alkyd resin and on a tung oil/linseed stand oil mixture are given and indicate the superiority of the former.—RPI. 4769

### 5.4.5

Factice Oils as Medium for Rust-Protective Paints. O. LOWE. *Ind.-Lack-Betrieb*, 19, No. 1, 10-11 (1951).

The advantages of factice oils, i.e., oils treated with sulphur chloride are discussed. They are economical in exhibiting little penetration of the substrate and show no tendency to rivet. Red lead does not settle in these oils. Their increased alkali resistance is of importance in protection against rust.—RPI. 4773

### 5.4.5

Selecting Organic Coatings for Metal Products. *Product Engineering*, 22, 173-180 (1951) Dec.

Discusses the factors affecting the above. Types of organic coatings and their principal uses are outlined. Illustrations.—BLR. 4909

### 5.4.5, 2.3.2, 5.3.2

The Problem of Painting Bright Chromium Plate. WARDLEY D. McMASTER. *Plating*, 38, No. 7, 696-698, 703 (1951).

Various precautions which have been taken in the past in an endeavor to ensure good adhesion of paint on chromium plate are briefly described, and it is shown that in all cases a certain number



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of failures was invariably encountered. However, the use of a hot chromium trioxide rinse containing 0.11 grams per liter chromium trioxide before painting ensured good adhesion. The work is allowed to air-dry without further rinsing. Full details are included on experiments carried out with other concentrations of chromium-trioxide. The use of phosphoric acid in place of chromium trioxide was not satisfactory, nor was a thorough degreasing treatment. Apart from the use of the chromium-trioxide pretreatment, the following conditions are suggested as important in ensuring good adhesion of organic coatings: 1. careful control of the plating bath, 2. adequate cleaning in the case of buffed parts, 3. the use of a paint or enamel which adheres well to steel, 4. an adequate baking, and 5. the use of a primer for those enamels which contain a significant proportion of aluminum flake pigment. It is shown that if failure does not occur when the painted specimen is exposed for 24 hours to an atmosphere of 100% relative humidity at 38° C. or to a water soak test of 2-4 hours at 38° C., it is unlikely that failure will occur in service. No difference in paint performance could be detected between specimens in which the chromium plate had been applied over steel, brass, or zinc.—MA. 4876

#### 5.4.5, 2.5, 2.3.7, 6.6.8

**Evaluation of Strippable Protective Coating for Acrylic Plastics.** HOWARD G. PFLEIDERER AND ROY A. MACHLOWITZ. *ASTM Bull.*, 59-62 (1951) Dec.

The work reported was performed to provide a basis for specifications covering the above. Tests were devised to evaluate sprayability, "delivery rate" vis-

cosity, effect on stressed plastics, usability in normal shop operations, stacking under load, adhesion, tensile strength, ultimate elongation, strippability after weathering, protection of stressed and unstressed plastic from paint materials, and storage stability. Test results on one satisfactory material are given, for illustration.—BLR. 4864

#### 5.4.5, 5.3.4

**Substitute Finishes for Electroplating: Organic Coatings in Today's Metal Finishing.** DONALD R. MESERVE. *Plating*, 38, No. 10, 1037-1039 (1951).

Several suggestions are made for the use of composite coatings of metal and paint, varnish, or lacquer. For example, reasonable life is claimed for chromium coatings applied directly to steel, brass, or zinc alloys without the customary nickel undercoat, provided the chromium plate is given a coat of clear lacquer. Alternatively, bright zinc may be used in place of chromium. Tinted clear coatings also offer many possibilities.—MA. 4902

#### 5.4.5, 5.4.8

**Rust-Preventive and Anti-Corrosive Paints.** H. RABATE. *Trav. peintures*, 6, No. 7, 191-193 (1951).

A short review of the principles of formulation of corrosion-resistant paints is given.—RPI. 4933

#### 5.4.5, 5.4.8, 3.3.2, 4.6.11

**Marine Under-Water Paints.** H. RABATE. *Peintures pigments vernis*, 27, No. 10, 619-628 (1951).

Marine corrosion and fouling are discussed. Red lead and zinc chrome are compared as corrosion-inhibitive pig-

ments. The use of conventional toxins and research on organo-metallic, organic and zeolite toxins are described and the mechanism of toxicity is briefly presented. Attention is directed to the practical problems of choosing a balanced painting system and of surface preparation and paint application.—RPI. 4933

#### 5.4.5, 6.4.2

**Paint Protection for Aluminum and Its Alloys.** *Ind.-Lack-Betrieb*, 19, No. 4, 65 (1951).

The increased use of aluminum has introduced the necessity for protecting the metal in marine and industrial atmospheres. Protection by metallic coatings and chemical treatment are briefly mentioned. Before painting, aluminum and its alloys should be cleaned by degreasers or mild abrasives as whitening or pumice. The use of emery or sand abrasion is not advisable. Paints containing copper or lead must be avoided. Phenolic and alkyd media and also zinc oxide form suitable components of paints for aluminum.—RPI.

#### 5.4.5, 5.4.7

**Paint, Surface Finish and Design.** L. A. JORDON. *Chemistry and Industry*, 1951, 981-987, Nov. 17.

Surveys the above. Causes of adhesion failure of paint films applied by spray are discussed as well as other factors concerned with spraying.—BLR.

#### 5.4.5, 6.4.2

**Paint Protection for Aluminum and Its Alloys.** *Ind.-Lack-Betrieb*, 19, No. 4, 65 (1951).

The increased use of aluminum has introduced the necessity for protecting the metal in marine and industrial atmospheres. Protection by metallic coatings and chemical treatment are briefly mentioned. Before painting, aluminum and its alloys should be cleaned by degreasers or mild abrasives as whitening or pumice. The use of emery or sand abrasion is not advisable. Paints containing copper or lead must be avoided. Phenolic and alkyd media and also zinc oxide form suitable components of paints for aluminum.—RPI.

#### 5.4.5, 8.1.2

**Rust Protection (In Industrial Coating Practice).** (In German.) OTTO GEHARDT. *Werkstoffe und Korrosion*, 2, 444-446 (1951) Dec.

Points out the great need for renewing the paint on weather-exposed iron and steel structures in Germany, discusses various passivating undercoatings and topcoats, properties of suitable pigment binders and the most recent development in silicone and fluorocarbon coatings.—BLR.

#### 5.4.5, 8.8.1

**Chemical Plants—Protection of Steelwork.** L. H. GRIFFITHS. *Iron & Steel* (London) 24, 504-506 (1951).

After stressing the importance of protecting mild steel against corrosive vapors in chemical plants, cleaning of the steel work is described and suitable coatings are considered. The latter include chlorinated rubber, Vi resin and synthetic rubber paints. The tendency of chlorinated rubber to run away from the edges of girders can be counteracted by applying glass tape over the wet paint at these edges and then saturating the tape with a further coat of

# DELTRAC Resiment

the Furane Resin Cement that

- **RESISTS CORROSION —**  
Acids, Alkalies, Solvents
- **SETS PERFECTLY —**  
Summer or Winter
- **WITHSTANDS HEAT —**  
Temperatures up to 375° F.

Highly efficient as a mortar for corrosion-resistant masonry, Resiment is low in porosity and high in compressive and tensile strength. It is supplied in the form of powder and liquid, in proper combinations, for mixing at time of use. Sets quickly by internal chemical reaction.

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"COPON" is now giving industry a truly remarkable new kind of protection against rust and corrosion from chemical fumes, acids, caustic, alkali and salt water. And it is combining its revolutionary protective qualities with other such desirable features as remarkable elasticity, exceptional long life, phenomenal tenacity to all types of metals. May we give you more facts—or send you sample for your own testing?



Available in Primers, Finishing Enamels and Paints in all colors.



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P. O. BOX 1113 • HOUSTON, TEXAS



chlorinated rubber. Synthetic rubber paints are very promising. They are unaffected by corrosive fumes and have sufficient flexibility to take up expansion of the steel without cracking.—RPI.

#### 5.4.5, 7.2, 4.5.2, 7.8

**Coatings for Underground Cables and Pipes.** F. E. KULMAN. *Paint and Varnish Production*, 41, No. 8, 8-14, 32-33 (1951) Aug.

Coatings and coating practices on the underground cable and gas piping systems of the Consolidated Edison Co. of New York, Inc. and the conditions under which these coatings are installed and operating. Causes of cable corrosion. 11 references.—MR. 4745

#### 5.4.6

**Rust Preventives: Existing Specifications Will Soon be Consolidated.** C. W. KELLEY and N. L. KLEIN. *Ordinance*, 36, No. 188, 321-322 (1951) Sept-Oct.

The rust preventive specifications in use by the Army, Navy and Air Force will be consolidated into 3 unified military specifications. These will be "Corrosion Preventive, Petrolatum Type, Hot Application"; "Corrosion Preventive, Solvent Cutback, Cold Application"; and "Corrosion Preventive, Fingerprint Remover."—INCO. 4892

#### 5.4.7

**Spraying Paint with Superheated Steam.** *Products Finishing*, 16, No. 3, 36-40 (1951). Dec.

A process for spraying products on a conveyorised finishing line using steam instead of compressed air has been developed by the Du Pont Company, and is covered by U. S. Patent 2,511,797. Advantages include 10-20% material savings; reduced pinholing and popping; reduced spray loss; increased film thickness per coat; possibility of applying finishes heavier in body and higher in solids.—EL. 4907

#### 5.4.7, 3.4.6

**Metal Spraying in Protective Atmospheres.** H. REININGER. *Metallüberfläche*, A, 5, No. 3, 42-43 (1951).

Reininger considers that spraying in atmospheres of inert or reducing gases, as a means of preventing oxidation, can only be effective if the whole operation is carried out in a special chamber from which air is excluded. The method is, however, uneconomical and never completely satisfactory owing to the unavoidable oxidizing action of the flame.—MA. 4925

#### 5.4.7, 6.3.19, 5.4.5, 5.9.1

**Painting Zinc and Its Alloys.** *Product Finishing* (London), 4, No. 10, 40-50 (1951) Oct.

The writer first discusses the factors which appear to influence the degree of adhesion of paint on zinc surfaces. He considers the chemical reaction between the zinc and some of the constituents of the paint, the smoothness and condition of the surface, corrosion after application and what is termed 'intrinsic adhesion.' Methods of preparing the surface to give increased adhesion include mechanical roughening, weathering, acid or alkaline etching, phosphate and chromate treatments. These last two are the most important and are dealt with at greatest length. A number of proprietary phosphate treatments are available, mostly based on zinc or manganese phosphates. The phosphate film places a physical barrier between the zinc and the paint

and also forms a key for the paint film on account of its rough crystalline structure. The use of air-drying paints is recommended over chromate passivated zinc surfaces. A short section on etching primers follows, and the rest of the article deals with the painting of zinc alloy die castings and sprayed zinc and galvanized coatings. It is unnecessary to apply any pretreatment to sprayed zinc, and almost any type of paint is said to be suitable. On die castings and galvanized surfaces a phosphate or chromate treatment is necessary.—ZDA. 4910

#### 5.4.7, 7.5.4

**Flotation Painting Gas Holders at 69,000 Square Feet an Hour.** L. B. DONOVAN. *Corrosion*, 9, No. 1, 1 (News Section) (1953) Jan.

Using a specially compounded paint which is pumped into the top of the water seal of gas holders of Consolidated Edison Company, New York City, the holders are painted at a very rapid rate, as high as 69,000 square feet an hour in the case of large holders. The holder first is lifted and the sides permitted to dry. As the holder is lowered, paint is pumped into the water seal space at a rate calculated to give the required thickness. After the tank is wholly descended, the gas is pumped back in and as it rises the excess paint is pumped out of the water seal space back into the tank truck from which it came. Tests show paint applied in this manner outlasts that applied by brushing. 4799

#### 5.4.8, 2.3.4

**Leaching Rate Tests and Anti-Fouling Paints.** O. IRISH. *Paint, Oil Chem. Rev.*, 114, No. 12, 16, 18, + (1951); Official Digest, Federation Paint and Varnish Production Clubs, No. 318, 433-440 (1951).

A description of the standard leaching rate test for anti-fouling compositions is given with a brief discussion on its utility and accuracy.—RPI. 4918

#### 5.4.8, 4.2.5, 4.6.11, 2.3.2

**Anti-Corrosive Paints for Marine Use.** H. RABATE. *Peintures pigments vernis*, 27, No. 4, 205-211 (1951).

A description of the organization of research, in France, into corrosion-resistant paints for naval and civil marine use. Methods of testing, examination and evaluation are given, with reference to photographic standards or breakdown, etc.—RPI. 4914

### 5.5 Oil and Grease Coatings

#### 5.5.1, 5.8.4

**"Cosmoline"—A Registered Trademark.** *Machinery* (New York), 57, No. 8, 199 (1951) April.

Cosmoline, a rust preventive, is a registered trademark. Erroneous references have been made to Cosmoline, using the term in a generic sense to designate the old heavy type grease preservatives. The series of "Cosmoline" includes, in addition to the heavy petrolatum types, a variety of thin-film resin-soluble types, polar types, inhibited lubricating oils, and waxy film and water-soluble grease types. Manufactured by E. F. Houghton & Co.—INCO. 4813

#### 5.5.1, 5.8.2

**Quick-Drying Rust Preventive Compound.** *Machinery* (N. Y.), 57, No. 9, 189 (1951) May.

Gulf No-Rust No. 6, is recommended for protecting metal surfaces against

corrosion in either indoor or outdoor exposure during domestic and overseas shipment, as well as during storage for long periods of time. This thin-film type rust preventive will provide surface coverage of 390 square feet per gallon and has no tendency to settle or separate in storage. When once applied and dried, it will not crack, chip, scale, or disintegrate at temperatures down to 0°F, nor will it flow at temperatures as high as 190°F. A coating not exceeding 0.008 in. in thickness is deposited by dipping at a temperature of 70°F, and it will dry sufficiently within 4 hours to permit handling without removal of the coating. This coating may be applied by brushing, spraying, or dipping and is readily removed with kerosene, Stoddard solvent, or similar petroleum solvents. Manufactured by Gulf Oil Corp.—INCO. 4814

### 5.7 Treatment of Medium

#### 5.7.9, 3.2.2, 4.6.6, 3.6.2

**Effect of Wetting Agents on Corrosion Resistance. II. Effect of Non-Ionic Wetting Agents.** (In German). LUIGI PIATTI. *Chimia* (Switz.), 5, No. 1, 811 (1951) Jan.; *Werkstoffe und Korrosion*, 2, 441-444 (1951) Dec.

Non-ionic wetting agents are shown to be more effective than ionic wetting agents in preventing the pitting effect of tap water and in removing tuberculation from steels. Tables and graphs show effect of type and concentration of wetting agent and of time of exposure. Includes photomicrographs.—BTR. 4861

#### 5.7.9, 4.3.3, 8.4.3

**Reduction of the Vanadium Content of Residual Petroleum Fuels by Solvent Precipitation.** W. SACKS. *Can. J. Technol.*, 29, No. 11, 492-495 (1951) Nov.

The removal of vanadium compounds from residual petroleum fuels of various grades by asphaltene precipitation was studied. Precipitation of vanadium, iron, and nickel with pentane asphaltenes, precipitation of vanadium with the asphaltenes of common solvents, and the analytical methods are discussed. Precipitation of the asphaltenes with normal-pentane removed similar amounts (83-95%) of the vanadium despite differing crude source, composition, and vanadium content of the original fuels. The major portion of the iron and nickel compounds were also removed with the pentane asphaltenes. The amount of vanadium removed by the solvent is approximately proportional to the asphaltene precipitated. Tables are included. 13 references.—INCO. 4940

### 5.8 Inhibitors and Passivators

#### 5.8.1, 5.5.1, 1.5

**Materials Engineering File Facts: Wlad Klad Kotes-Corrosion Preventives.** *Materials & Methods*, 34, No. 6, 109 (1951) Dec.

Table, revised Aug. 1951 to conform with the latest government specifications, gives the various Wlad Klad Kotes corrosion preventives, including the solvent types, petrolatum grease types and oils, the government specifications, descriptions, uses, applications, removal and protection requirements.—INCO. 4857

#### 5.8.2, 5.4.5, 4.6.1, 6.2.3

**Coatings for Fixed Steel Parts Submerged in Water.** (In German). *Metall-*

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oberfläche, Sec. A, 5, A143 (1951) Sept.  
Results of a series of experiments on  
rust-inhibiting coatings show the superi-  
ority of a hot mixture of bituminous  
coal-tar pitch and micro-asbestos. Rust-  
inhibiting properties of other types of  
coatings.—MR. 4903

5.8.2, 5.6.1  
**Volatile Crystals Prevent Corrosion  
of Packaged Steel Parts.** PHILIP O'KEEFE,  
*Materials & Methods*, 34, 84-86 (1951)  
Dec.  
Presents a new method of preventing  
the corrosion of packaged steel articles  
by moisture. The vapor from the crys-  
tals condenses on the metal surfaces or  
dissolves in condensing moisture. The  
steel must be enclosed, although hermetic  
sealing is not necessary. Can be applied  
as a powder, dissolved in alcohol and  
sprayed into solution for metal dips, or  
used as a coating on wrapping papers.  
Discusses properties, test results, and in-  
dustrial applications.—BLR. 4816

5.8.2, 5.8.4, 4.6.1, 7.10  
**Corrosion Inhibitor.** *Materials & Meth-  
ods*, 34, No. 3, 130, 132 (1951) Sept.  
Cor-in, a solution of active materials  
in organic solvents, acts as a neutralizer  
and destroys the corrosiveness of all  
moisture of water vapor that comes in  
contact with it. After application by  
brush, spray, or dip, the solvents evapo-  
rate, leaving a loosely adhering film of  
crystals which vaporize into the sur-  
rounding air. When water vapor comes  
in contact with the vapors of Cor-in, it  
is claimed to be made non-corrosive.  
Applications include die-making, hand  
tools, cutting tools, work in progress  
and parts for shipment and storage.—  
INCO. 4837

5.8.4, 5.7.8, 4.6.2  
**The Development of Organics for  
Water Treatment.** J. A. HOLMES, Natl.  
Aluminate Corp. Paper before Midwest  
Power Conf., Chicago, April 4-6, 1951.  
*Proc. Midwest Power Conf.*, 13, 238-245  
(1951).  
Development of organic materials for  
use in water treatment. Work to date  
has been on tannins, lignins, sulphite  
liquors, alginates, glucosates and starches.  
Various workers disagree as to the exact  
function of organics. Whether they af-  
fect solubility or hold up reaction rates  
in a manner similar to polyphosphates  
has never been definitely decided. Im-  
portant requisites for organics used in  
boiler sludge conditioning are that they  
eliminate deposits, help to prevent cor-  
rosion and embrittlement, will not cause  
foaming and are stable under conditions  
encountered inside the boiler. Diagrams  
and photomicrographs are included. 15  
references.—INCO.

5.8.4, 5.8.2  
**Research on the Composition of Coal  
Tar and Its Derivatives (23rd Report).**  
On the Application as a Corrosion In-  
hibitor (1st report). E. FUNAKUBO, M.  
TAGAYA, J. TOKURA AND A. ADACHI, *Coal  
Tar (Japan)* 4, No. 3, 66-69 (1952)  
March.  
The inhibitive effect of coal tar deri-  
vatives on the corrosion rate of steel spec-  
imens in 10% sulfuric acid was ex-  
amined. Tests were carried out at tem-  
peratures of 30°, 50° and 70° C for 30  
minutes using the following three  
methods:  
1. Determination of the amount of  
evolved hydrogen.



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★  
**HOT DOPE**  
 Straight from the Kettle  
 on PIPE PROTECTION

★  
 By Boyd Mayes

"Why," asked a pipeliner friend, "do you loaf around the entrance to that bank almost every Tuesday noon?"

"Not loafing; just the shift we picked to watch our investment," we told him. "Thought you were in the pipe coating & wrapping business . . . not banking," he ribbed back.

"Everybody's in the banking business," was the best answer we knew. "We got in the pipe coating and wrapping business through the front door of that bank and we've been watching each other ever since. Bought a share or two of their stock to keep a closer eye on 'em. Being 'in' with a banker is as good as being 'in' with a grocer, and an investment in a bank share comes next, to our way of figuring, to having a house to come home to and a car to drive to work. Besides," we told our inquisitive friend, "we got an unforgettable lesson in the fine art of finance at the ripe old age of 14 back in our East Texas piney-woods hometown. Decided to go in the sign-painting business, found it took \$10.00 capital outlay and hit the local bank president up for a loan."

"Sure," he said, "just sign this note for \$10,000," and shoved nine one-dollar bills across the desk. The note was signed when we counted the money.

Figuring banks, and particularly bank presidents, didn't make mistakes we asked in a low, and humble, tone of voice: "But where's the other dollar?"

"Oh . . . that . . ." he explained with a broad smile and a hearty slap on our back as he ushered us to the door, "that's interest taken out in advance!"

That day was the beginning of our dream to someday own a part of a bank . . . even one share!

**MAYES BROS.**

1150  
McCurry

HOUSTON, TEXAS

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2. Determination of the weight loss of steel specimens.

3. Determination of the bending number of steel specimens.

Through the results obtained, dodecyl pyridine chloride proved to be the best, and coal tar base (230-250° C fraction) was second best.—JSPS.

## 5.9 Surface Treatment

### 5.9.1

**Finishing Magnesium. I.—Cleaning, Pre-Treatment, and Chemical-Finishing Methods.** *Product Finishing* (London), 4, No. 7, 40-51, 92 (1951).

A review of acid and alkali cleaning procedures, mechanical surface treatment methods, and chemical and electrochemical produced conversion coatings for magnesium. The various types of treatment included in the latter groups include: chrome pickle, sealed chrome pickle, bright chrome pickle, R. A. E. 30-minute bath, alkaline dichromate, modified alkaline dichromate, chrome-sulphate, Melanizing, chromealum, chrome-phosphate, dichromate, caustic pressure, selenious acid, galvanic anodizing, caustic anodizing, dichromate-phosphate anodizing, and the Manodyz process.—MA. 4908

### 5.9.1, 6.2.3, 5.4.5

**Help Your Steel to Hold Its Protective Coating.** A. J. LIEBMAN. *Chem. Eng.*, 58, No. 9, 326, 328, 330-331 (1951).

Preparation of steel before painting is discussed, the physical properties required in paints for various types of surface being outlined. On a ground or sandblasted surface the film thickness should be at least three times the depth of pits. The advantages of phosphate treatments and etch primers are explained.—RPI. 4768

### 5.9.2

**Metal Cleaning in Aqueous Media. I. An Examination of the Problem. II. The Properties of the Materials to be Removed. III. The Initial Reactions in the Removal of a Residue. IV. The Complete Removal and Dispersal of Residues. V. Physical and Mechanical Assistance in Aqueous Degreasing Process.** P. D. LIDDIARD. *Metal Industry*, 79, 63-64, 91-93, 107-109, 123-127, 151-153; (1951) July 27, Aug. 3, Aug. 10, Aug. 17, Aug. 24.

I. Presents a study of problems of the above. Discusses the necessity of cleaning metal surfaces, and methods suitable. In Parts II and III, fundamental questions concerning adhesion, wetting, spreading, contact angle, and equilibrium forces at surfaces are discussed. Part IV studies those materials which are available and evaluates their use as cleaners. Data on surface-active compounds are tabulated. Part V gives a brief description of the forms of mechanical agitation found in degreasing practice. 20 references.—BLR. 4763

### 5.9.2, 5.3.4, 6.4.3, 6.3.6

**Pickling and Electroplating Beryllium-Copper Alloy Components.** *Products Finishing* (U. S.), 16, No. 2, 22-48 (1951) Nov.

The advent of a lightweight nonferrous metal, such as beryllium-copper, has filled a real need in industry in replacing steel in certain applications. Characteristics of the beryllium-copper alloys with respect to corrosion are taken up in detail, reasons for plating these alloys,

and necessary surface conditions and heat treatments are discussed. Detailed steps for pickling and treatment prior to plating are given.—TDD. 4911

### 5.9.2, 6.4.2, 6.3.19

**The Cleaning of Metals in Engineering Processes.** I. B. MCKENZIE. *Australasian Engr.*, 1951, Dec. 87-93+.

Alkaline cleaning is the cheapest method, but for aluminum and zinc articles only mild alkalis may be used, and for cleaning tinned ware sulphite must be present to prevent corrosion. Electrolytic cleaning is recommended where the highest degree of cleanliness is required, for instance, before electroplating. Methods of solvent cleaning include washing in petroleum distillates, and vapor degreasing in trichlorethylene or perchlorethylene. Emulsifiable solvent cleaners consist of an emulsifying agent, such as triethanolamine oleate dissolved in a solvent, usually kerosene. With diphasic cleaners the work is exposed to the simultaneous action of a solvent which preferentially wets the metal and water. 33 references.—MA. 4811

### 5.9.3

**Blast Cleaning: A Recently Developed Method of Using the Cleaning Power of Abrasive Blast without the Limitations of an Enclosed Booth.** *Product Finishing* (London), 4, No. 4, 40-43 (1951).

A new dustless, blast cleaning method for the removal of paint, scale, rust corrosive products, etc. from metal surfaces is described.—MA. 4905

### 5.9.3, 6.4.2, 5.3.4

**Wet Blasting Permits Direct Chrome Plating on Aluminum.** H. E. LINSLEY. *American Machinist*, Editorial Staff. *Am. Machinist*, 95, No. 17, 120-121 (1951) Aug.

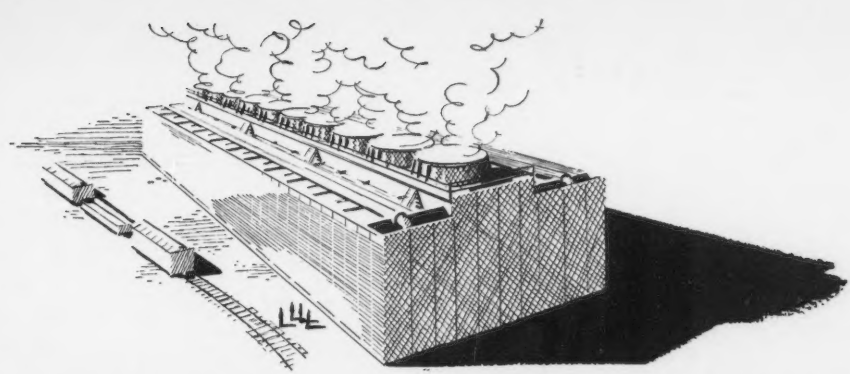
The direct plating of aluminum is difficult because the rapid formation of an oxide film prevents satisfactory adhesion between the base and the plating metal. Thus, one common method of chrome-plating aluminum involves cleaning, chemical zinc coating, and copper-nickel plating before application of the final chromium plate. In another popular method, the aluminum is cleaned and then anodized before chromium plating.

In the new Cro-Plate two-step method, oxides and dirt can be removed from the work piece by wet-blasting, a process that minutely peens and greatly enlarges the surface thus ensuring a good bond. The process also leaves a protective coating of water and abrasive which protects the article from rapid oxidation during transfer to the plating tank. In the tank, which is located as close to the wet-blasting unit as possible, the chemically inert abrasive washes off and falls to the bottom. Although standard plating equipment and solutions may be used after wet blasting, a proprietary high-speed solution called Cro-Sol permits deposition of about 0.008 inch of chromium per hour. Two self-contained plating units, Cro-Platers, differing only in power requirements, permit close automatic control of temperature, current density, and other variables; and deposit the desired plating thickness to within  $\pm 0.00001$  inch.

The deposited coating has a hardness of 75-82 Rc which explains the increase in wear resistance. The impact value of wet-blasted and plated aluminum is said to approximate that of unplated mild steel.

The two-step blast and plate method has





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Threshold Treatment <sup>\*\*</sup>

Threshold Treatment with Calgon stops corrosion at its source by forming a protective film right on the corroding metallic surface. This protective Calgon film ends corrosion problems. Calgon can also be used to stop the deposition of calcium carbonate scale.

Threshold Treatment is adaptable for use in once-through or recirculating cooling water systems, and is designed to protect *all* the metal in the system; tubing, piping and heat transfer surfaces.

Our engineers will be glad to show you what Threshold Treatment with Calgon can do for you. A letter or phone call will put their years of experience with corrosion problems of all kinds at your disposal. Or write for a copy of the free booklet, "Calgon Controls Corrosion."

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\*\*Threshold Treatment with Calgon for controlling corrosion licensed under U.S. Patent 2,337,856



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killing  
rust and  
corrosion  
for 32  
years—  
Do you  
know how?

We Will  
Gladly Send  
You Complete  
details on  
Request—  
Write on your  
letterhead to:



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North Kansas City, Missouri

been applied successfully to wrought, sand-cast, and die-cast aluminum; and also, on an experimental basis, to steel, titanium, and magnesium.—PDA. 4786.

#### 5.9.3, 7.5.5, 5.4.5

**Repainting Steel Water Tanks.** J. O. JACKSON. *Water & Sewage Works*, 98, 160-163 (1951).

The use of paint for preventing or reducing corrosion in steel water tanks is discussed. Methods of cleaning the surface of tanks before painting (e.g., sand-blasting, wire brushing, and etc.) are outlined and suitable paint materials for the interior and exterior of tanks are suggested.—RPI.

#### 5.9.4

**Chromizing.** C. H. KALPERS, *Brennstoff-Warme-Kraft*, 1951, 416, Dec.

Chromized tubes installed in steam condensers have given satisfactory results in cases where difficulties with the expanding of the tubes have been experienced. It was found that these tubes remain practically free from scale encrustation; and this may be due to an influence of the chromium content in the surface of the tube upon the crystallization process of the scale forming constituents. Chromized condenser tubes show a better corrosion resistance than 17 percent chromium iron tubes. Air preheater tubes for boiler plant have been chromized. These tubes, of which 300,000 pieces were chromized, were 47 mm. in diameter, 1 mm. thick and 1.86 meters long. Chromized component parts are scale resistant at temperatures up to 850 degrees.—TIME.

#### 5.9.4

**Metal Conservation by Chromizing.** H. KALPERS. *Metall*, 5, Nos. 23, 24; 546-548 (1951).

The B.D.S. method of chromizing is briefly described and the application of chromized steel are discussed. Because of its high resistance to corrosion it can often be used as a satisfactory and eco-and bronze.—MA.

#### 5.9.4, 6.3.19

**Conversion Coatings on Zinc and Zinc Alloys.** *Product Finishing* (London), 4, No. 9, 47-57 (1951) Sept.

Under most conditions of atmospheric exposure, zinc forms a grey, tightly adherent film which hinders attack on the reactive metal, but where water may lie in contact with the zinc, the corrosion products do not hinder its rate of corrosion and some additional protection is required. Chromate treatment gives better protection under most conditions than does a phosphate treatment on zinc which is not intended for subsequent painting. Various chromate treatments are described, including Cronak, Iridite, chromate-formate, and chromate-fluoride and solutions for treating zinc anodically. Reference is made to specification DTD923 and A.S.T.M. Standard B201-49T for chromate finishes. A section describes experiments to determine the extent to which conversion coating increases the corrosion resistance of zinc. Other processes mentioned include the chromic acid bright dips, the formation of chromated protein films and the use of alkaline chromate treatments.—ZDA. 4915

#### 5.9.4, 6.4.2

**The Alodine (Alocrom) Process, a New Method for the Protection of Alu-**

**minum and Its Alloys.** A. POLLACK. *Metall*, 5, Nos. 19/20, 434-436 (1951).

A brief, illustrated account of this method of protection, which uses an aqueous solution of phosphate, chromate, and fluoride. The oxide film produced has a high electrical resistance, a hardness approximately 50% greater than that obtained with the Eloxal process, and is heat-resistant up to the melting point of the basis metal.—MA. 4899

#### 5.9.4, 6.4.2

**Surface Treatment for Aluminum.** *Light Metals Bull.*, 13, No. 13, 457 (1951).

A process for surface treating aluminum has been developed which provides a simple and rapid method of producing satisfactory paint base coatings on aluminum and aluminum alloys. The qualities claimed for this process include superior resistance to corrosion, effectiveness in localizing corrosion, in the case of scratches, increased paint adhesion, and enhanced appearance even without paint. Operating sequence instructions are given, and a number of illustrations show the difference in behavior of plain and treated aluminum surfaces.—TIME. 4779

#### 5.9.4, 6.4.4

**The R. A. E. Hot Half-Hour Chromate Bath for the Protection of Magnesium Alloys.** L. F. LE BROCC AND H. G. COLE. *Protection and Electrodeposition of Metals*, Selected Government Research Reports, Vol. 3, (1951) p. 1-50.

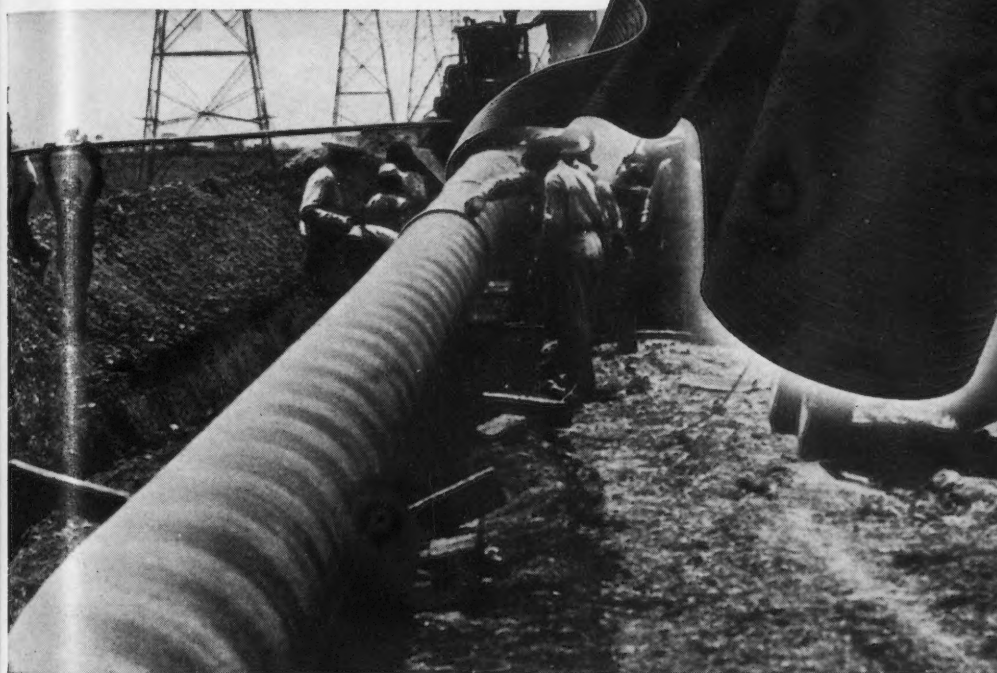
The effect of temperature, concentration, salt ratio, and pH on the production of chromate films on pure magnesium and on magnesium alloys was examined in detail, and the influence was determined of variations in composition likely to occur during prolonged use of the hot ½-hour chromate bath, and of impurities likely to gain access to the bath. A method of rejuvenating a much-used bath is described. It is shown that chromate films of good appearance can be produced on magnesium alloys by solutions containing chromates alone. The rate of formation of the film is slow, whatever the pH. Above pH 6.5 the addition of sulphates has little effect, but below this, the rate of reaction increases rapidly with falling pH value. A good chromate film may be obtained in a reasonable time from a chromate-sulphate bath under many combinations of operating conditions, but the bath described representing a fair working compromise, is simple to prepare, and may be used for the treatment of any commercial magnesium alloy. The composition of the bath is:  $K_2Cr_2O_7$  1.5,  $(NH_4)_2Cr_2O_7$  1.5,  $(NH_4)_2SO_4$  3.0 g. per 100 c.c.,  $NH_4OH$  (0.880 sp.gr.) 0.35 c.c. per 100 c.c. A valuable feature of the bath is that at the pH normally used, heavy-metal salts are precipitated, and do not therefore cause contamination. Contamination by magnesium does not appear to be objectionable. Chlorides do not interfere with the operation of the solution, but they may not be used to entirely replace the sulphate in the bath. 4 references.—MA. 4782

#### 5.9.4, 6.4.4, 5.3.4

**Chromate Treatments for Magnesium Alloys with Special Reference to Cold Baths.** L. F. LE BROCC. *Protection and Electrodeposition of Metals*, Selected Government Research Reports, Vol. 3, 1951, p. 90-119.

Experiments are described which resulted in the development of a cold sim-

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Upper Right—An Equitable Gas System 20" line through rough country. Upper Left—First coat of Roskote being sprayed on this line in the field, no primers needed. Bottom—The pipe is then wrapped with Royston Glas-Wrap and given a second coat of Roskote.

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ple immersion bath and of a cold electrolytic bath for the chromate treatment of magnesium alloys. The immersion bath consists of  $\text{Na}_2\text{Cr}_2\text{O}_7 \cdot 2\text{H}_2\text{O}$  10,  $\text{KMnO}_4$  5,  $\text{K}_2\text{SO}_4 \cdot \text{Al}_2(\text{SO}_4)_3 \cdot 24\text{H}_2\text{O}$  10g./100c.c. This gave results equal to those obtained with the hot bath. The electrolytic bath consists of:  $\text{Na}_2\text{Cr}_2\text{O}_7 \cdot 2\text{H}_2\text{O}$  15,  $\text{KMnO}_4$  5,  $\text{NaOH}$  0.2 g./100 c.c. This gave results superior to those obtained with the hot bath under the same conditions. A cold 10% solution of  $(\text{NH}_4)_2\text{CrO}_4$  was found to be a useful reagent for removing corrosion products from corroded magnesium-alloy parts. 4 references.—MA. 4772

#### 5.9.4, 8.9.1, 6.4.2

**Easier Way to Fight Salt Spray.** S. H. REINIGER. *Aviation Week*, 55, No. 8, 37-38, 43-44 (1951) Aug. 20.

Production of corrosion-resistant metal surfaces is being sped in aircraft plants by use of newer processes that are said to be more efficient and easier to apply than anodizing, which has been the method generally used. One of these newer methods is "Alodizing," developed by the American Chemical Paint Company. Heart of this modern treatment is "Alodine," a protective coating chemical which forms a surface on aluminum alloys that is tough, non-metallic, and integral with the metal. Like anodizing, the Alodizing process creates a surface on aluminum that anchors paint, prolongs paint life, and acts as a "backstop" against corrosion if the paint is damaged. Alodine is claimed to give better corrosion-resistance to metals than anodizing and is cheaper and simpler to apply.—TDD. 4937

#### 5.9.4

**The Thermal Stability of Phosphate Coatings.** A. DOUTY. *Plating* (U. S. A.), 38, No. 11, 1163 (1951) Nov.

In answer to a reader's query it is stated that manganese phosphate coatings are believed to withstand long periods of heating at temperatures between 225° and 275°F., and that stoving zinc phosphate coatings for 15 minutes at 350°F. before painting did not affect the adhesion of the paint or its resistance to corrosion and high humidity. The effects on thermal stability of the different acid dips which sometimes follow phosphating are not known.—ZDA.

#### 5.9.4

**Surface Protection via Phosphate Coatings.** M. G. CRANDELL. *Can. Chem. Processing*, 35, No. 12, 994-996, 998-999 (1951) Dec.

Bonderite is a chemical compound that produces a phosphate coating on iron, steel, zinc, cadmium, and aluminum and their alloys increasing the adhesion of the applied paints, enamels, and lacquers, resulting in a longer lasting, corrosion resistant finish. Bonderite is also used as an aid in the deep-drawing of metal acting as an anti-flux that aids materially in preventing welding, scoring, and galling, increasing drawing speeds, and prolonged tool life. Parco Compound, another rust-resisting finish, changes the surfaces of iron or steel to an insoluble phosphate coating that is highly resistant to corrosion.—INCO.

#### 5.9.4

**A Bright Dip for Steel.** G. E. GARDAM. "Protection and Electro-Deposition of Metals," His Majesty's Stationery Office (London), 1951, p. 133-134.

Process which produces a bright me-

tallic luster on mild steel, medium carbon, plain and alloy steels. The surface, however, is not sufficiently smooth to give clear image reflection but a method of improving the appearance of tarnished, corroded, pickled or similar surfaces is provided. Composition of the dip and the technique.—MR.

#### 5.9.4, 2.5

**Conversion Coatings and Specification Finishes.** C. O. HUTCHINSON. *Products Finishing* (U. S.), 1951, 26-36 (Sept).

The author discusses the importance of preparatory treatment for all types of metals prior to the application of the quality finishes. The specifications of these coatings, such as phosphate and oxide, are taken up in detail; also, the influence that U. S. Government agencies have exerted in the writing of these specifications is emphasized. One table lists Iron and Steel Conversion Coatings, their specification titles and numbers, their grades and types; a second table provides the same information for nonferrous conversion coatings; and the third table lists the specification numbers and descriptive titles of military equipment and the division that uses them.—TDD.

#### 5.9.4, 6.2.3

**The Chromizing Process.** T. GIBSON. *Metal Treatment and Drop Forging*, 18, No. 68, 201-204 (1951).

A patented process is described for the conversion of the surface of an ordinary steel into a chromium-iron alloy containing a high percent of chromium. The article, packed in ferro-chromium, is maintained at 1050°-1100° C. for several hours during which time anhydrous hydrochloric acid is passed into the retort to generate chromous chloride. The gaseous chromous chloride reacts with the iron to form ferrous chloride, thus depositing chromium atoms on to the surface, and these subsequently diffuse inwards. No change in dimensions takes place and the coating is integral with the rest of the article and cannot be mechanically stripped.—MA.

#### 5.9.4, 6.2.5, 6.3.1

**The Chromizing Process.** T. GIBSON. *Sheet Metal Inds.*, 28, No. 290, 569-571, 575 (1951).

The present-day shortage of high alloy steels and non-ferrous metals emphasizes the importance of suitable substitutes. Gibson describes a method of chromizing iron or steel to produce good corrosion- and heat-resisting surfaces. Chromizing is claimed to be of established use in many industries, including the chemical industries, oil refineries, carburizing plant, etc.—MA.

#### 5.9.4, 6.4.2

**New Protective Treatment for Aluminum Simplifies Processing at Reduced Costs.** R. STRICKLEN. *Materials and Methods*, 35, No. 2, 91-95 (1952) Feb.

A chromate process for the treatment of aluminum alloys has been developed by Allied Research Products Inc., known as Iridite No. 14. The film is amorphous and non-porous, and is about 0.00001 in. thick. It is not as hard as aluminum oxide. Treatment does not produce embrittlement. Intensity of color and degree of corrosion resistance vary with the thickness of the film and with the alloy. A clear film of Iridite No. 14 on the interior surface of skin sections pro-

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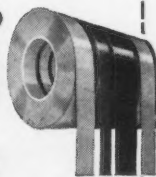
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vides good adhesion for the interior coat of primer. The yellow film, formed by a two-minute treatment, on 24S-T3 aluminum is approximately equal in protective value to anodic films resulting from 20-minute treatment in sulphuric acid or 30 minutes in chromic acid. The coating compares favorably with chromic and phosphoric acid anodizing treatments for painting aluminum surfaces. Compared with anodic films, Iridite No. 14 has an extremely low electrical resistance to direct current and to low and high frequency alternating current. The Iridite treated surface may produce a fluxing effect in shielded arc welding. The preparation methods used for this acid chromate process are conventional and are selected after consideration of the alloy composition, the type and extent of the surface contamination, and the end-result desired. A typical dip solution is made up as follows: Iridite No. 14, 3 ounces per gallon of solution; temperature, 75 to 95° F; pH, 1.5 to 1.7; time, 10 seconds to 5 minutes.

It is believed that this pretreatment provides a better bond for rubber than does anodizing.—ALL.

#### 5.9.4, 6.4.2, 1.3

**Anodizing and its Ability to Protect Aluminum Alloys.** A. FRANSSON. *Iva* (Sweden) 22, 154-157 (1951).

This is a review of the methods of applying protective oxide films on aluminum and its alloys with the use of chromic acid anodic oxidation techniques. Applications of the methods to duralumin and 24S have been successfully made for many years. The alloy 75S (low in copper but with 5 to 6 per-

cent zinc) with somewhat lower resistance to corrosion in the unprotected state is likewise responsive to such treatment. ML 31 is a malleable alloy of percentage composition copper 2.3, silicon 0.13, manganese 1.5, iron 1.1, chromium 1.2, and nickel 1.2, used in jet-engine compressors for parts subjected to atmospheric abrasion at temperatures about 100° C. Intercrystalline corrosion that develops on its surface during atmospheric or self oxidation also yields to anodizing treatment. The Martin Hard Coating process (MHC) applies a layer 150μ thick, from 10 to 15 times that formed by anodizing.—ALL.

### 5.11 Design-Influence on Corrosion

#### 5.11, 6.2.2, 6.2.1

**Designing with Modern Materials: Powder Metals.** *Machine Design*, 23, No. 10, 325-327 (1951).

Recent developments in powder metallurgy are briefly discussed and the advantages of the process indicated. Information is presented on ferrous powder materials, the effect of copper infiltration, corrosion and wear-resistant sintered iron, ductile sintered iron, and friction materials.—MA. 4812

#### 5.11, 6.3.1, 6.6.1

**Designing with Modern Materials.** *Machine Design*, 23, No. 10, 297-350, 352 (1951) Oct.

Comprehensive survey of the latest developments in engineering materials including ferrous and non-ferrous metallics, powder metals, and non-metallics

including ceramics and refractory materials, plastics and rubbers, and a miscellaneous section on finishes, insulations and lubricants. Boron-treated alloys, heat and corrosion-resistant steels, high strength, high toughness steels, precipitation hardening stainless steels, electrical steels, centrifugally-cast steels, ductile cast iron; and of the non-ferrous group, aluminum alloys, magnesium and magnesium alloys, copper and copper-base alloys, beryllium-copper alloys, titanium and titanium alloys, molybdenum, tungsten, and tungsten alloys, heat and corrosion resistant alloys containing chromium and nickel, cemented carbides and rare earth alloys are discussed. Graphs and many tables giving the properties of the various materials are included.—INCO. 4810

### 6. MATERIALS OF CONSTRUCTION

#### 6.2 Ferrous Metals and Alloys

##### 6.2.1, 6.3.1, 1.6

**The Behaviour of Engineering Metals.** H. W. GILLET. 9 x 6 in. pp. xvi + 395, with 58 illustrations. 1951. New York: John Wiley & Sons, Inc. (\$6.50); London: Chapman & Hall, Ltd. (52s).

"Behavior is truly measured by conventional mechanical tests only in very exceptional cases, for behavior is a composite of many attributes, some of which cannot be measured quantitatively." The above quotation exemplifies the outlook of the author throughout his book.

Since the volume is intended in the first place for the engineer technical terms have been used as little as possible. In the first six chapters basic ideas are discussed, corrosion, surface stress, internal stress precipitation, hardness, heat treatment, ductility, brittleness, and so on, and in sufficient detail to be really intelligible. The next fourteen chapters deal with specific materials, both ferrous and non-ferrous; whilst in the three final ones special considerations are discussed, including the vital factors of cost and availability.

##### 6.2.2, 3.5.1

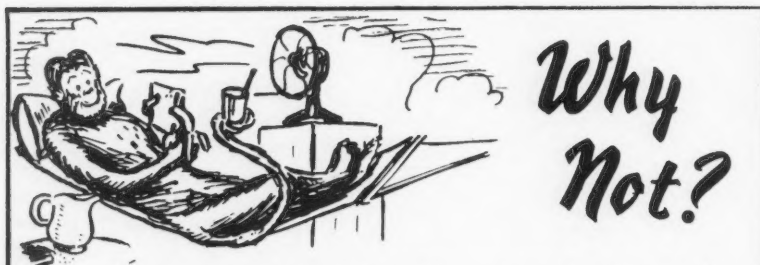
**Properties and Application of Ductile Iron.** G. L. Cox (Inco). *Iron & Steel Engr.*, 28, No. 12, 75-83; Disc. 83-84 (1951) Dec.

Properties of ductile iron, compared with conventional materials, are unique. These properties including ductility, impact, compressive strength, damping, machinability, wear resistance, surface hardening, fatigue, weldability and corrosion resistance are discussed. Graphs, tables, photomicrographs and 12 references are included.—INCO.

##### 6.2.2, 6.2.3, 6.2.4, 5.2.1

**Iron, Mild Steels, and Low-Alloy Steels.** C. P. LARRABEE AND B. J. KELLY (U. S. Steel Co.). *Ind. and Eng. Chem.*, 43, No. 10, 2239-2242 (1951) Oct.

Discussion of corrosion and the use of iron, mild steels, and low-alloy steels as chemical engineering materials of construction. The use of cathodic protection for solving the problems of corrosion is one of the methods reviewed. The review also points out that spherical cast iron continues to find increased use and it is expected that it will replace other grades for many years. 49 references.—INCO. 4750



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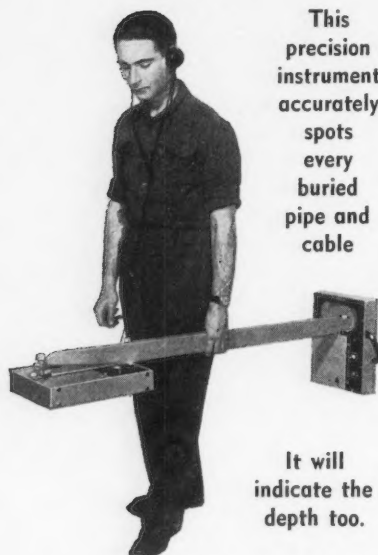
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### 6.2.3

I. Low Carbon Steels. II. Medium Carbon Steels. *Materials & Methods*, 34, 99, 101 (1951) Aug.

I. Data sheet gives compositions, physical and mechanical properties, thermal treatments, fabricating properties, corrosion resistance, available forms, and uses for five of the above steels. II. Data sheet gives compositions, physical properties, mechanical properties, thermal treatments, fabricating properties, corrosion resistance, available forms, and uses for four of the above steels.—MR. 4858

### 6.2.3, 8.1.2

The Corrosion of Steel in Steel Houses. Department of Scientific and Industrial Research, Nat'l. Building Studies, Report No. 16, 29pp, 1952.

An examination of the corrosion of steel work in steel-clad and steel-framed houses. Relating to the protection required in the cavities of steel-clad and steel-framed houses, a limited survey of houses built between 1920 and 1927 was undertaken in 1947 to obtain information on behavior of the protective coatings then given. Description of houses examined and condition of steelwork and protective coatings are given. The various factors involved in corrosion of the types of structures examined are summarized. Of these the correct design of details is of major importance. The main conclusions of the survey are listed. Illustrations are included.—INCO. 4795

### 6.2.3, 4.3.2, 4.4.2

Corrosion—Carbon Steels with Acids. MARS G. FONTANA. *Ind. and Eng. Chem.* 43, 75A-76A, 78A (1951) Dec.

Reviews a Russian report on the effect of acid concentration on the corrosion rate of carbon steels.—BLR.

### 6.2.4, 1.7.1, 8.9.4, 2.2.3

Interim Report of Service Trails of Steel Coal Wagons (1939-1950). J. C. HUDSON. Brit. Iron & Steel Res. Assoc. Atmospheric Corr. Sub. Comm., Paper MG/BB/57-50, April 1951. *J. Iron & Steel Inst.*, 169, Pt. 3, 250-256 (1951) Nov.

Service trials have been in progress since 1939 on floor plates of four different compositions built into 100 steel coal wagons belonging to British Railways. Observations indicate that the life of the plates should be about 25 years in mild steel but should be doubled by the use of copper-bearing steel or low-alloy steels of the copper-manganese or copper-chromium type. These contain 0.01-0.04 nickel. The superstructure of coal and mineral wagons should be built of copper-bearing or low-alloy steels.—INCO.

### 6.2.4, 3.7.2, 2.3.4

On Acid Resisting Silicon-Steel. (In English). ISHIRA IITAKA AND KAZUHIKO SEKIGUCHI. Reports of the casting Research Lab. of Waseda Univ. Tokyo, No. 2, 5-6 (1951).

Corrosion resistance of 5.5% silicon steel to hydrochloric acid adding various quantities of copper to improve the resistance was studied. Each specimen was cast as a cylindrical rod in green sand mold and machined. Surface was polished with emery paper and cleaned with alcohol and ether. Corrosion tests were carried out in 5% hydrochloric

acid, 20% hydrochloric acid, 5% sulfuric acid, 5% nitric acid and 10% acetic acid. Tests at indoor temperature were carried out for 5 hours and those at boiling temperature for 2 hours. Weight losses were measured. It was concluded that 5.5% silicon steel has greater resistibility to hot and cold hydrochloric acid than carbon steel. 5.5% silicon steel containing 2 or 5% copper has an excellent resistibility, its durability is equal to that of 18-8. Nickel addition to it gives good influence upon its resistance because copper solid solubility in iron is increased with nickel, galvanic cell that is the cause of pitting corrosion being eliminated. The addition of chromium improves corrosion resistance in some degree without injuring the resistibility to hydrochloric acid.—INCO.

### 6.2.5, 1.3

Stainless Steels and Other Ferrous Alloys. WALTER A. LUCE. *Ind. and Eng. Chem.*, 43, 2258-2271 (1951) Oct.

Comprehensive literature survey. Methods for reclaiming critical elements and substituting titanium for niobium. The sigma phase, its nature, occurrence and effects on stainless steel. Data on corrosion and heat resisting alloys and application in industry. A resumé of stainless-steel production procedures. 328 references.—MR. 4777

### 6.2.5, 2.5, 5.3.4

Tentative Recommended Practice for Preparation of and Plating on Stainless Steel. *Plating*, 38, No. 8, 837-845 (1951).

Discusses the nature of stainless steel and its surface peculiarities. The preparation of stainless steel for plating involves three basic steps. i. Removal of scale. ii. Removal of oil, grease and fabricating lubricants by anodic cleaning. iii. Activation before plating, i.e., removal of the thin transparent film of oxide that is inherent on the surface. Activation is carried out in a 20-50% solution of sulphuric acid at 150°-180°F. (with the higher temperature for lower concentration acid) for at least one minute. This will produce a dark adherent smut which is removed in the plating bath. Great care should be taken in racking for the plating cycle. Post-plating operations such as buffing and coloring can be carried out in the usual manner.—EL. 4865

### 6.2.5, 3.7.3, 3.2.2

The Question of Intercrystalline Corrosion of 18-8 Type Steel During Single-Pass Butt Welding. A. G. MAZEL. *Acetogenoe Delo* (Acetylene Welding), 22, 7-9 (1951) Mar.

The influence of temperature and duration of heating for various types of welding on corrosion of 18-8 was investigated. Data are discussed and tabulated.—BLR. 4923

### 6.2.5, 3.8.3

Passivity of Type 304. R. KNOX, JR. Alan Wood Steel Co. *Metal Progress*, 60, No. 3, 77-78 (1951) Sept.

During plant investigations, corrosion tests were run on 3 heats of Type 304 stainless steel in aqueous solution of sulfuric acid at 140-180°F containing 1.25% sodium chloride. In the course of the tests, some phenomena were observed and these are discussed. The hypothesis that the passivation phenomenon which was exhibited by specimens from 2 heats of Type 304 might be caused by the presence of residual molybdenum in the amounts of 0.18 and 0.17% respectively, was suggested. The 3rd heat of 18-8

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-0.12	Lead .....	+0.32
-0.14	Tin .....	+0.30
-0.23	Nickel .....	+0.21
-0.40	Cadmium .....	+0.04
-0.44	IRON.....	0.000
-0.56	Chromium .....	-0.12
-0.762	Zinc.....	-0.32
-1.33	Aluminum .....	-0.89
-1.55	Magnesium.....	-1.11

\*U. R. Evans, "Metallic Corrosion, Passivity & Protection"  
Rusting is an electrochemical action in which iron replaces hydrogen, or a metal, in an electrolyte. Each metal has its own definite activity in this respect, which is termed its electro-potential. A list of the metals arranged in increasing order of activity, with their electro-potential expressed in volts is called the Electromotive Series. For convenience — at the right hand side of the above table — the zero point has been placed at iron and the figures, since they are relative only, have been transposed to show the metals' activity relative to iron.

THE RUST-PROOFING of iron and steel products is a "sacrificial" function of metallic zinc which for many years has accounted for the metal's largest single use. Nearly 50% of all the zinc consumed in the United States is used for galvanizing. This "sacrificial" characteristic of zinc in providing iron and steel with low-cost protection against rust is also responsible for the increasing use of the metal in the form of anodes for the cathodic protection of pipe lines and other underground iron and steel structures. The property of zinc which makes this possible is due to the metal's advantageous position in the electromotive series. As indicated by the listing on the right, zinc — of the commonly available metals — stands far enough below iron so that its electronegative potential provides effective and economical cathodic protection, but not so far as to sacrifice itself needlessly in doing its job.

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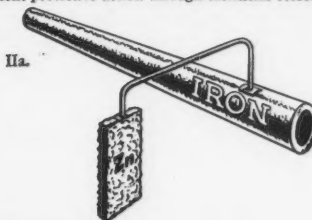
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which did not show the passivity phenomenon, contained no molybdenum.—INCO. 4756

### 6.2.5, 8.8.5

**It Pays to Pamper Stainless.** E. M. RAINS. *Armco Steel Corp. Sheet Metal Worker*, 43, No. 3, 40-41 (1951) Dec.

Proper care in handling your stainless sheets, whether they be 18-8 or 17 chromium stainless, is important when you stop to think that every spoiled piece of work is that much metal lost. Pictures are given to illustrate how to care for stainless sheets in handling and storage.—INCO. 4929

### 6.2.5

**1. Colubium and Tantalum in Austenitic Stainless Steels. 2. Columbium-Tantalum Alloys and Their Use in Type 347.** 1. JEROME STRAUSS. 2. H. A. GROVE. *ASTM Bulletin*, 17-19 (1951) Oct.

Presents data showing that the substitution of the presently available 40% niobium-20% tantalum ferro-alloy for the standard type of ferro-columbium previously used is practicable. Mechanical properties and corrosion resistances of the steels thus produced are tabulated and charted.—BLR.

### 6.2.5, 2.3.4

**Corrosion Data of Welded Low-Carbon Stainless Steel.** H. F. EBLING AND M. A. SCHEIL. A. O. Smith Corp. *Welding J.* (N. Y.), 30, No. 10, 511s-518s (1951) Oct.

Corrosion resistance of welded, heat-treated alloys and weld deposits of the unshielded low-carbon Type 304 (18-8) were determined and compared to the stabilized grades of 18 chromium-8 nickel alloys containing niobium, niobium-tantalum or titanium. Corrosion resistance was based on the standard boiling nitric acid test. The low-carbon Type 304 alloy suitable for lining process chemical equipment was found to be equal or better in corrosion resistance than the stabilized grades of 18-8 alloys after normal fabricating heat treatments and for use where service temperatures do not exceed 800°F. The low-carbon Type 308 weld deposit was found to have good corrosion resistance except after low temperature stress reliefs of the as-welded condition. Exposure for 1000 hr. at 900° or 1000° F resulted in poor corrosion characteristics, over 51 mils per year in boiling nitric acid. Pictures and tables are included, 10 references.—INCO.

### 6.2.5, 3.2.2, 3.7.3

**Influence of Vacuum Melting on the Properties of 25% Chromium Ferrites.** (In French). J. HOCHMANN. *Rev. met.*, 48, 734-758 (1951) Oct.

The action of vacuum remelting made under well-defined conditions on certain properties of 25% chromium ferritic stainless steels is examined. Analyses degasification conditions, charge composition, hydrogen content, and synthetic casting techniques. Influence on properties with respect to friction, shock resistance, and inter-crystalline corrosion after treatment at 900-1200°C., and with respect to hardening, fragility, and intergranular corrosion after heating between 400 and 500°C., was investigated. Includes photomicrographs, tables, and graphs. 39 references.—BLR.

### 6.2.5, 4.3.2

**Corrosion—Durimet 20 with Sulfuric Acid.** M. G. FONTANA. *Ind. & Eng. Chem.*, 43, No. 9, 105A-106A (1951) Sept.

Summary of Corrosion data in chart form presenting concentrations and temperatures for corrosion of Durimet 20 (29 nickel, 20 chromium, 2 molybdenum, 3 copper, 1 silicon, 0.07 carbon, bal. iron) by sulfuric acid.—INCO.

## 6.3 Non-ferrous Metals and Alloys—Heavy

### 6.3.6

**Low-Copper Nickel Silver of Improved Chemical and Physical Properties.** DOUGLAS W. GROBECKER, DENTON T. DOLL, AND JAMES M. TAUB. U. S. Atomic Energy Commission Publ., 1951 (LA-1324), 34 pp.

An investigation was made of a 40:32:28 copper-nickel-zinc alloy for castings. The alloy was melted by high frequency heating in graphite crucibles, and the charge analysis was maintained to within  $\pm 0.75\%$  for all constituents. A slag cover of 52% soda ash, 27% borax, and 21% silica, with a m.p. of  $\sim 815^\circ\text{C}$ ., was used to prevent excessive zinc oxidation and was thickened before pouring by the addition of 30-40 wt.-% silica to facilitate removal by skimming. The metal was cast in graphite moulds preheated to  $\sim 500^\circ\text{C}$ ., and relatively sound castings of various shapes were made. The solidification shrinkage was fairly high, resulting in some shrinkage cavities, but it is suggested that the casting properties of the alloy might be improved by minor addition of tin without adversely affecting the physical or chemical properties. The alloy has superior corrosion-resistance to commercial nickel silvers in most media tested, combined with higher ultimate tensile strength, hardness, and elongation. Possible economic usages for the alloy are as non-corrosive springs, precision instruments and pressure application and in the marine, architectural, and food-handling industries.—MA.

### 6.3.6, 7.2, 7.6.5

**Corrosion of Copper on a Circulating Evaporator.** L. W. HAASE. *Metaloberfläche*, Ausgabe A, 5, No. 11, A170-A171 (1951) Nov. Translation available as B.N.F. Serial 35,834.

Considers that rust particles in the water are responsible for the corrosion of 99.96% copper through which rises the boiler feed water and condensate which is evaporated under low pressure. Reference is made to the work of Campbell (Brit. Non Ferrous Metals Res. Assoc.) on pitting corrosion in copper water pipes which however, appears to have no bearing on the case considered.—BNF.

### 6.3.8, 4.3.2

**Corrosion—Lead with Sulfuric Acid.** M. G. FONTANA. *Ind. & Eng. Chem.*, 43, No. 9, 105A-106A (1951) Sept.

Summary of corrosion data in chart form presents temperatures and concentrations for the corrosion of lead by sulfuric acid.—INCO.

### 6.3.10, 4.3.2

**Corrosion—Ni-Mo-Cr Alloy with Sulfuric Acid.** MARKS G. FONTANA. *Ind. & Eng. Chem.*, 43, 113A-114A+ (1951) Nov.

Describes effects of concentration and temperature on corrosion of a nickel-base nickel-molybdenum-chromium alloy known as Chlorimet by sulfuric acid.—BLR.

### 6.3.10, 6.2.5, 4.3.2

**Nickel Alloys Versus Sulfuric Acid.** *Intern. Chem. Eng. & Process Inds.*, 32, No. 6, 284-286 (1951) June.

Monel and other high nickel alloys are used in handling sulfuric acid solutions since they are most resistant to corrosion. Monel equipment is used in organic sulphonations, manufacture of soaps, petroleum refining, extraction and polymerization of olefins, organic esterifications and condensations, acid treatment of coal distillates, ammonium sulphate production, aluminum sulphate, inorganic acid sulphates, and textile processing. Inconel has adequate resistance to cold un-aerated sulfuric acid solutions up to about 70%. Alloys containing from 60-80 nickel, and from 13-20 chromium, with the rest iron, are used for electrical resistance and heat-resisting purposes and are somewhat similar in corrosion resistance to Inconel. Nickel-Resist is employed chiefly with dilute un-aerated solutions at atmospheric temperature.—INCO.

### 6.3.15, 2.3.7

**A Realistic Approach to the Use of Titanium.** H. H. HANINK. *Product Eng.*, 22, No. 11, 164-171 (1951) Nov.

Tensile properties, fatigue strength, creep-rupture tests, hardness and impact properties for commercial titanium, Ti75A, Ti50A (titanium-2.5%, chromium-1.4%, iron 0.25% oxygen) and Ti170A (titanium-chromium-iron). Both rolled specimens and engine forgings were examined. Alloys were found to be notch sensitive.—BNF.

### 6.3.15, 6.3.20, 3.6.6, 3.7.2, 4.3.1

**Corrosion Studies on Titanium and Zirconium Metals; Semiannual Report for June 1951.** L. B. GOLDEN, I. R. LANE, JR., J. T. PONS, W. R. ACHERMAN AND W. MACE. *Metals Corrosion Lab., Bureau of Mines*. 41 pp.

Tests have been made on the corrosion resistance of zirconium and zirconium alloys in hydrochloric acid (embrittlement tests), sulfuric acid and phosphoric acid. A comparison was made of the relative corrosion resistance of low-hafnium arc-melted zirconium and zirconium containing less than 3% hafnium induction-melted in graphite. A series of zirconium alloys was subjected to tests in various rocket fuels and synthetic ocean water spray. Corrosion rates were determined for zirconium and stainless steel in aqua regia. Titanium, zirconium, and stainless steel were also tested in ammonium chloride solutions and boiling synthetic ocean water. Titanium and lead were exposed to sulfuric acid and nitric acid mixtures. Galvanic corrosion tests were conducted on titanium coupled with magnesium, zinc, aluminum, lead, tin, nickel, and copper. Galvanic potentials and corrosion rates were determined in synthetic ocean water, 1% hydrochloric acid, and 1% sodium hydroxide solutions. Solution potentials were determined in substitute ocean water under different conditions of aeration. Open circuit potentials were determined and the potential of each metal relative to the saturated calomel half-cell was recorded for magnesium, tin, and nickel coupled with titanium.—NSA.

### 6.3.15, 6.3.20, 4.3.1, 3.6.6

**Corrosion Studies on Titanium and Zirconium Metals; Semiannual Report**

for July-December 1951. L. B. GOLDEN, D. SCHLAIN, I. R. LANE, JR., W. L. ACHERMAN, AND W. MACE. Metals Corrosion Lab., Bureau of Mines. 47 pp.

Corrosion data have been obtained for titanium, zirconium, and stainless steel in various concentrations of sulfuric acid, nitric acid, hydrochloric acid, and phosphoric acid. The effect of mixed acid solutions on zirconium was determined. Titanium, zirconium and stainless steel were also tested in inorganic chlorides, hypochlorite solutions, and organic compounds. Embrittlement tests in concentrated hydrochloric acid under pressure were made on zirconium-tin alloys. Zirconium-titanium alloys (induction melted (in graphite) were exposed to the corrosive action of phosphoric acid, hydrochloric acid, and sulfuric acid. The corrosion resistance of arc melted zirconium-titanium alloys was determined in cupric and ferric chloride solutions and in aqua regia. A series of zirconium alloys was subjected to tests in various rocket fuels. The complete resistance of all these alloys to attack by anhydrous hydrazine was of special interest. Galvanic couple tests and electrode potential measurements involving titanium in synthetic ocean water and 0.1N hydrochloric acid and zirconium in synthetic ocean water indicates that these metals are electro-positive (noble) with respect to certain common metals. Copper, aluminum, tin, lead, magnesium, and zinc undergo rapid galvanic corrosion, copper and monel are attacked moderately, and nickel corrodes very slowly. Magnesium coupled with zirconium in synthetic ocean water is rapidly consumed by galvanic action. Although titanium and zirconium show small losses in weight under certain conditions, corrosion rates are always under 1 mil per year.—NSA.

### 63.15, 6.3.20, 4.3.2

**Corrosion Studies on Titanium and Zirconium Metals;** Monthly Report for September 1951. L. B. GOLDEN, D. SCHLAIN, I. R. LANE, JR., W. L. ACHERMAN, AND W. MACE. Metals Corrosion Lab., Bureau of Mines. 8 pp.

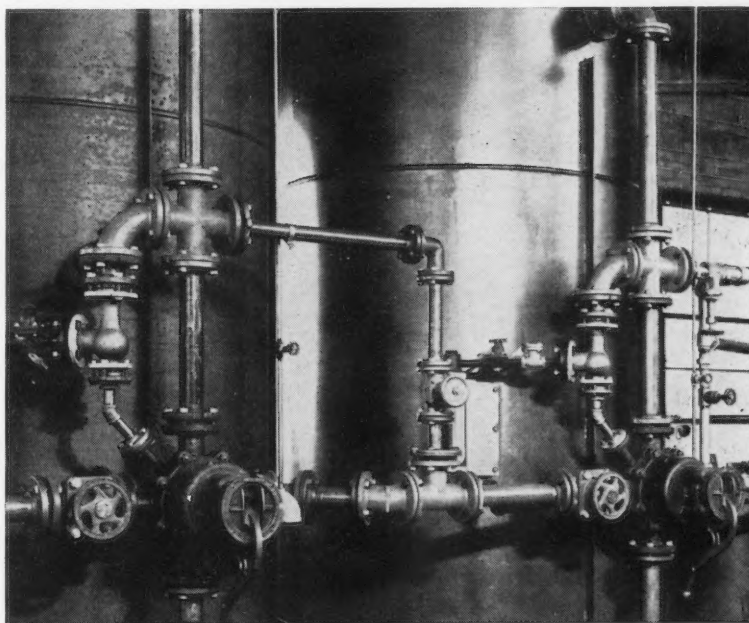
Results of corrosion studies are given for titanium, zirconium, and Carpenter No. 20 stainless-steel corrosion by phosphoric acid aerated with helium; titanium, zirconium, stainless steels and Hastelloy C corrosion by calcium and sodium hypochlorite; titanium-zirconium alloys corrosion by sodium, nickel and aluminum chlorides; titanium-lead couples galvanic corrosion in synthetic ocean water; titanium-metal couples corrosion in synthetic ocean water aerated with helium; and zirconium alloys corrosion by rocket fuels.—NSA.

### 63.15, 8.10.2, 8.8.5

**Titanium: Problems Attending Its Extraction and Fabrication.** N. P. HARVEY. *Iron Coal Trades Rev.*, 163, Nos. 4347, 4348; 233-237, 295-299 (1951).

A review is given of the metallurgy of titanium. Its occurrence and the Kroll, van Arkel, and de Boer methods for producing the metal in powder form are described. After consolidation by sintering or melting in special furnaces, the metal can be fabricated by hot and cold working, machining, and welding. Corrosion-resistance and anodizing are discussed, and some alloying systems with titanium and mechanical properties are also surveyed. 19 references.—MA.

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## 6.4 Non-ferrous Metals and Alloys—Light

### 6.4.2, 5.3.4

**Protection of Aluminum by Nickel Plate Over Synthetic Base Resists Corrosion and Erosion.** *Precision Metal Molding*, 9, No. 12, 49 (1951) Dec.

New type of hard, stress-free and erosion resistant surface coating for aluminum is identified by the trade name Alni-Clad. The process involves the plating of nickel on aluminum by means of a synthetic base applied to serve as an intermediate coating between the base metal and electroplate. So far applications have been confined to the aircraft industry. Developed by Bart Laboratories Co., Inc.—INCO. 4894

### 6.4.2, 5.9.1

**Surface Treatment of Aluminum and Its Alloys** (French and German.) B. MAUDERLI. *Aluminium Suisse*, Nos. 3, 4, 5, 6; 98-105, 125-135, 180-190, 221-225 (1951).

Mauderli begins with an outline of the effect of the method of manufacture of a component on the mechanical polishing operations employed. Consideration is also given to the origin of typical defects revealed after polishing, as well as the behavior of the main alloy groups when so treated. This is followed by a section dealing with the cleaning and degreasing of articles by solvent and chemical means. Protective chemical treatments of the alkali-chromate type are described, and the Alodine (Alcrom) and Bonderite 170 processes are mentioned. Anodizing and electro-brightening processes are described, and defects arising from the use of unsuitable material or fabrication methods, and contamination by foreign metals are illustrated. The concluding section reviews applied finishes for aluminum, with particular reference to the effect of pretreatment on adhesion, as well as lacquers for application to collapsible tubes and impact-extruded containers.—MA. 4849

### 6.4.2, 5.9.4, 2.3.2

**Corrosion of Surface Treated Aluminum Alloys.** F. M. REINHART, Nat. Bur. Standards, Report No. 1004, Project No. 4105, May 25, 1951, 9 pp.

Report of an investigation to determine the corrosion rates of aluminum and magnesium alloys used in aircraft, when exposed to a marine atmosphere and in the tidewater. The results evaluating the protection given by Bonderite 170 and Alrok 14 surface treatments on aluminum alloy 24S-T3, both painted and unpainted, when exposed to tide-water, marine atmosphere, salt spray cabinet and dry laboratory atmosphere are summarized. On the basis of the tests, the Alrok treatment provided somewhat better protection than the Bonderite 170 treatment. Work was sponsored by NACA, Bureau of Aeronautics of the Dept. of the Navy, and the U. S. Air Force. Graphs, tables and photomicrographs are included.—INCO. 4926

### 6.4.2, 5.9.4, 2.3.2

**Mechanical and Corrosion Tests of Spot-Welded Aluminum Alloys.** F. M. REINHART (Nat'l. Bur. Standards), W. F. HESS, R. A. WYANT, F. J. WINSOR, AND R. R. NASH (Rensselaer Polytechnic Inst.). NACA Tech. Note 2538, Dec. 1951, 74 pp.

Corrosion behavior of spot-welded

aluminum-alloy (alclad 24S-T3, 24S-T3, alclad XB75S-T6, XB75S-T6, and R-301-T6) panels of varying weld quality was determined. Tide-water and weather exposure tests were made at the U. S. Naval Air Station, Hampton Roads, Va. by the National Bureau of Standards and the results were evaluated in terms of distribution of corrosion products and effects on weld strength. Panels were welded at Rensselaer Polytechnic Institute and after exposure were returned to the Institute for mechanical tests and metallographic examination to determine the extent and type of corrosion attack. Numerous illustrations.—INCO. 4927

### 6.4.2, 7.8

**Metallurgical Considerations in the Use of Aluminum for Cable Sheathing.** I. and II. A. LATIN. *Metallurgia*, 44, Nos. 264, 265; 167-173, 231-238 (1951) Oct., Nov.

Part I discusses factors of availability of materials, production methods, alloy properties, and sheathing methods (extrusion, die sinking, forming, and welding), and special methods. Part II deals with properties of drawn and extruded tube, corrosion protection, and joining. Illustrations, graphs, and tables.—BLR. 4743

### 6.4.2, 8.1.2

**Aluminum in Building.** Northern Aluminum Co. Ltd. Book, 111 pp. Published by the Company, Bush House, Aldwych, London, W.C.2.

Gives full details of the use of aluminum in building under the following headings: Aluminum as an architectural medium; public and private buildings; external applications; internal applications; services equipment and fixtures; industrial buildings; prefabricated buildings; fabricating and finishing; assembly and maintenance; aluminum paint and metal spray finishes. It is illustrated throughout and blue prints are also given. An index is provided.—BNF. 4804

### 6.4.2, 8.8.1

**The Most Recent Applications of Aluminum in the Chemical Industry.** P. JUNIERE. *Aluminium Suisse* (Switzerland), No. 5, 163-172 (1951) Sept.

Containers for nitric acid, acetic acid, etc., were the first application of aluminum in the chemical industry. Among the uses of aluminum in France during the last 10 years are mentioned a distilling apparatus made of 99.5% aluminum, Al-S4G, A-U4G, A-G3, and Al-SG alloys used for sugar-beets and fruits, and equipment in the charcoal industry. Metal of 99.5%—99.8% aluminum has also proved satisfactory for storage and transportation of hydrogen superoxide. The alloys A-G3, A-S4G, and A-S13 are used in the artificial resin manufacture. Aluminum is widely used in the petroleum industry: aluminum-magnesium alloy for tanks, aluminum-magnesium-silicon alloys for pipes, aluminum-silicon alloys such as A-S4G, A-S13, and A-S10G especially for parts of distilling equipment. Pipe lines for fluids and gas are made of 99.5% aluminum. The most recent application of aluminum is in the construction of equipment for molecular distillation, which makes the distillation of materials with a high molecular weight (fatty acids, vitamins, perfumes etc.) possible. Aluminum is not attacked by several of the modern cleaning media, because of which storage tanks are often made of

aluminum or aluminum plated steel. The method of joining aluminum by argon arc welding will probably increase the field of application of aluminum in the future.—ALL. 4727

### 6.4.2, 8.8.1

**Durability of Aluminum and Its Alloys:** The Chemical Industries. *Light Metals* (England), 14, Nos. 163, 164 and 165; 541-546, 639-643, 662-667 (1951) Oct., Nov., Dec.

Aluminum's resistance to corrosion for the majority of industrial chemicals has made it particularly useful in the production and transportation of commercial chemicals. In certain instances aluminum may be further protected against attack by artificially thickening the natural oxide film on the metal, or protection may be increased by application of a coating. Inhibitors can prevent or minimize corrosion. Cathodic protection will lengthen the life of aluminum equipment. Many chemicals are stored in aluminum, one of the main features in this connection being the fact that aluminum does not cause any change in color. Since aluminum and its alloys are highly resistant to oxidation and scaling they are most suitable for condenser tubes, for there is no layer formed which will interfere with the heat transfer. Aluminum is used widely in sewage disposal plants, in handling explosives and fertilizers. The soap, paint and varnish industry make good use of its corrosion resisting qualities. Animal and vegetable oils, and some acids are processed using aluminum.—ALL. 4771

### 6.4.2, 2.3.6, 2.3.9, 3.2.2

**Corrosion Figures by Anodic Attack of Aluminum.** (In French.) RAYMOND JACQUESSON AND JACK MANENC. *Rev. met.*, 48, No. 11, 879-882 (1951) Nov.

The determination of crystal orientation by the pits formed by attack with Lacombe's reagent is usually completely satisfactory, but two difficulties have been encountered in applying this method to the edges of sheet aluminum: 1. the metal not having been subjected to the same amount of work throughout its thickness is not uniformly reactive, and 2. a curious degeneration of the corrosion figures occurs. Suppose, for instance, that a virgin crystal gives sq. pits. After light (50%) rolling, the new figures formed on the previously polished surface as a result of the deformation are slightly turned towards one another and have lost one of their right angles symmetrically. This phenomenon does not occur after anodic attack. The authors investigated the effect of the current density on an anodic attack in 5% hydrochloric acid. At low current density (0.5 amp./cm.<sup>2</sup>), the corrosion figures are few and relatively large; at higher current density (0.8 amp./cm.<sup>2</sup>) they are smaller and much more numerous. There is an optimum current density which in the above case is 0.6 amp./cm.<sup>2</sup>; in 5% hydrochloric acid + 2% nitric acid it is 0.4 amp./cm.<sup>2</sup>. It is necessary that the metal should be electrolytically polished and the bath fresh and of high resistivity, or alternatively that the metal should have been immersed in a soda bath until the first bubbles of hydrogen are liberated. This method can also be applied to alloys, such as Duralumin.—MA.

### 6.4.2, 3.7.3, 4.3.7

**Relation Between the Deformation Texture of an Aluminum-Magnesium**



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**Alloy and Its Behaviour in the Presence of Mercury.** (In Italian). P. A. JACQUET AND A. R. WEILL. *Metallurgia Italiana*, 43, 51-65 (1951) Feb.—MR.

#### 6.4.2, 7.5.5, 8.8.1, 8.4.3, 8.3.5

**Aluminum Alloys (as Chemical Engineering Materials of Construction.)** H. W. FRITTS AND E. D. VERINK, JR. *Ind. Eng. Chem.*, 43, No. 10, 2197-2199 (1951) Oct.

Part of the fifth annual Materials of Construction Review. Covers specifications for tank and pressure vessel construction; applications in the chemical, petroleum and food process industries; aluminum foil; aluminum air preheaters for power stations. 49 references.—BNF.

#### 6.4.2, 7.10

**Development and Possible Uses of Very Pure Aluminum.** (In German). W. HELLING AND H. NEUNZIG. *Metall.*, 5, Nos. 19-20, pp. 424-426 (1951) Oct.

Properties of 99.99% aluminum alone or alloyed with 0.5% or 2.3% magnesium (Reflectal alloys). Uses: in electrolytic condensers, as jewelry and for highly polished parts.—BNF.

#### 6.4.2, 8.9.2

**Examination of Aluminium Mudguards from Lanchester Motor Car Built in 1903.** G. I. METCALFE. *Light Metals* (England), 14, No. 161, 469 (1951) Aug.

An examination was made of the aluminum mudguards from a Lanchester motor car built in 1903. They were constructed from aluminum sheet 0.050 in. thick, shown by spectrographic analysis to contain iron 0.8 percent, silicon 0.8 percent, titanium 0.15 percent. The most interesting observations were: 1. the generally sound condition of the material after nearly fifty years of service; 2. the absence of corrosion around rivet holes where copper rivets had been used; 3. the comparatively small amount of corrosion attack of the aluminum where it came into direct contact with the iron bracket; 4. the successful use of a lead-containing primer paint which is contrary to recommended modern practice; 5. the excellent adhesion of the paint to the aluminum in spite of the surface having only been shot blasted prior to application of the paint.—ALL. 4920

#### 6.4.2, 8.10.3, 5.11

**Duralumin Mine Skips and Cages.** *Light Metals* (England), 14, No. 161 455-460 (1951) Aug.

In designing mining applications of duralumin advantage should be taken of the high ratio of proof stress to ultimate stress and the elastic deformation of Duralumin is much greater than that of steel, and it has a correspondingly higher capacity of absorbing energy under impact. Vickers-Armstrongs, Ltd. have developed a skip or cage of composite construction, comprising a Duralumin body built of plates and rolled sections riveted together with fittings of steel and forged Duralumin and carried in a steel bridle frame.

Service conditions: Duralumin skips have been used in South African gold mines for periods of up to 18 years. Only in very adverse conditions as in contact with moisture of strongly alkaline or acidic character does any serious corrosion occur. In the presence of moisture there is a tendency for Duralumin to corrode where it is in metallic contact with iron or steel. To lessen the ef-

fects of corrosion due to damp or wet conditions, Aldural—a metal consisting of a sandwich of Duralumin "B" with a homogeneous rolled-on coating of pure aluminum on each side—is used.

Treatment of Duralumin: To bend Duralumin during construction, the plate or section is heated and held for a short time at the annealing temperature of 360°C (680°F) and then quenched in cold water. If a large amount of forging or smithing is to be done, the material should be heated to a temperature between 420 and 450°C (790 and 840°F), worked while hot and subsequently heat treated at 480-500°C (895-930°F), and quenched. The metal can be easily cut up by the use of an oxy-acetylene flame.

Protection: Surfaces should be carefully coated with zinc chromate paint before installation and periodically washed and repainted to assist in preventing surface corrosion. Where steel and Duralumin parts meet metal-to-metal contact should be prevented by coating with zinc chromate paint or the insertion of fiber washers or thin stainless-steel washers, or strip.

Rivets and riveting: Duralumin "B" rivets which are supplied in the soft state should be heat treated and quenched in the same manner as plates and angle bars; heading should be completed soon after quenching. "MG-5" rivets have been developed for cold heading as received. For successful heading of Duralumin rivets, the clearance of the holes should be kept to a minimum, and not exceed + 1/16 in.—ALL. 4783

#### 6.4.4, 3.6.6, 4.2.7

**Technical Note on Tropical Corrosion Tests on Magnesium Alloy Sheets in Contact with Other Metals.** L. F. LE BROCO AND T. L. WILLIAMS. *Protection and Electrodeposition of Metals*. Selected Government Research Rep. Vol. 3. (1951) p. 224-226.

Corrosion Tests simulating inland tropical conditions showed that over a period of 221 days some corrosion and pitting occurred on unpainted chromate-treated magnesium-alloy sheet at points of contact with other metals, but away from these points practically no corrosion occurred. The contact metals used were anodized Duralumin, untreated brass, passivated and unpassivated zinc-plated steel, and passivated and unpassivated cadmium-plated steel. Magnesium alloys of high purity and of normal grade were included in the test, and the latter suffered greater attack than the former. The contact corrosion caused by Duralumin was markedly less than that caused by other metals. Observations were also made on the corrosion of the individual metals. Anodized Duralumin and untreated brass were only slightly tarnished. The unpassivated zinc-plated specimens showed attack after a few days' exposure, and during the test the coating completely broke down. The passivated zinc showed greatly reduced attack compared with the unpassivated. Cadmium-plated parts, both passivated and unpassivated, showed very little attack, the attack being of the same order as that on passivated zinc. The tests show clearly that chromate-treated magnesium alloys, especially high-purity material, even when unpainted, are much more resistant to inland tropical conditions than zinc plated parts, unless the latter are passivated.—MA. 4781

#### 6.4.4, 5.9.4

**Anti-Corrosive Treatments for Magnesium.** T. KAWAMURA. Paper before 1st World Metallurgical Congr., Detroit, Oct. 1951. Proc. 1st World Metallurgical Congr. ASM, 1951, 645-650.

Two improvements on the original Bengough anti-corrosive process for magnesium are described. The one improvement is intended for magnesium that is unlacquered and consists in sealing the selenium film produced in the Bengough process. The sealing is done by boiling the film in boiling water and then heating in air for 30 minutes at 230°C. The other improvement is intended for lacquered magnesium and consists in subjecting the magnesium alloy to a Bengough treatment followed by a Sutton treatment before lacquering. Tests were made in saline solutions. Illustrations.—INCO. 4761

#### 6.4.4, 5.9.4

**The Influence of Surface Contamination on the Corrosion of Magnesium Alloy Sheet to Specification D.T.D. 118.** L. RAKOWSKI. *Protection and Electrodeposition of Metals*. Selected Government Research Rep. Vol. 3, 1951, 187-215.

The difficulties experienced in obtaining uniformity of chromate films under various conditions were investigated. These difficulties are shown to be due to surface contamination and surface heterogeneity of the alloy. The surface inclusions revealed by the chromate treatment are the source of the accelerated corrosion under sea-water spray conditions. Greatly improved corrosion-resistance was obtained on metal which had been scoured with wet pumice or given a chemical etching treatment capable of dissolving foreign-metal inclusions. The improvement consisted mostly of the elimination of deep localized pits. 6 references.—MA. 4928

#### 6.4.4, 2.3.2

**Variations in Corrosion Properties on Different Parts of Magnesium Alloy Sheet.** E. R. W. JONES AND M. K. PETCH (Appendix on The Determination of Small Amounts of Iron in Magnesium Alloys. A. Bacon and H. C. Davis.) R. A. E. Report, February 1944. *Government Research Reports* (England), 3, Protection and Electro-Deposition of Metals, pages 171-186. His Majesty's Stationery Office, London 1951.

Sea-water spray corrosion tests were carried out on chromate-treated specimens selected at regular intervals from large sheets of magnesium alloys to specifications D.T.D. 118 and 120A, in order to discover any variation in corrosion from part to part of the sheets. In material to specification D.T.D. 118, a large systematic variation occurred and was found to be associated with a similar variation in the iron content of the material. It has not been found possible to eliminate the effects of the variation in comparative tests of surface treatments by a method of calibration of the sheet material, and it is therefore considered that such tests on the material are unsatisfactory. Some variation also occurs in material to Specification D.T.D. 120A but this is of a lower order and is apparently random. It is considered that such a variation could be due to the conditions of the corrosion test, but this does not invalidate the use of the present type of test for comparing protective treatments on this material. A method for the determination of small amounts of iron in magnesium alloys is given in an appendix.—ALL.

## 6.5 Metals—Multiple or Combined

### 6.5, 1.3

**Titanium, Zirconium, Molybdenum, Tungsten, Tantalum, Niobium, Vanadium, and Hafnium as Engineering Materials.** JOHN L. EVERHART. *Materials & Methods*, 34, No. 6, 89-104 (1951).

Materials and Methods Manual No. 77. A review of physical and mechanical properties, fabrication, weldability, methods of finishing, and present and future application.—MA.

### 6.5, 6.1, 1.5

**How to Tackle Materials Substitution.** *Product Engineering*, 22, No. 10, 123-146 (1951) Oct.

"Aluminum Output Improves" (pp. 138-139) is concerned with substitution of aluminum for steel or copper. "Magnesium Confined to Military Applications" (pp. 140-141) points out that magnesium is practically unobtainable for non-military uses in the U.S.A., but gives mechanical properties, etc., of several magnesium-lithium-base alloys. Other sections advocate use of powder metallurgy (p. 142), deals with substitutes for copper/nickel/chromium electrodeposits (p. 143) and for copper (p. 145), and mention (pp. 145-146) substitutes or possible applications for lead, tin, nickel, zinc, molybdenum and clad metals.—BNF. 4913

### 6.5, 6.6.7, 4.3.1, 4.4.1

**Effects of Weed and Insect Sprays on Spraying Equipment Materials.** J. J. PATTERSON AND G. L. SHANKS. Manitoba Dept. of Agriculture & Immigration, Winnipeg, Canada. Publication No. 246, Oct. 1951, 16 pp.

Experiments conducted to determine the effects of the more common weed and insect sprays on materials which might be used in the manufacture of spraying equipment. 24 different materials were used, including metals, such as black iron, aluminum sheet, galvanized iron sheet and plate, zinc sheet, tinmed iron, copper sheet, brass sheet and stainless steel, non-metals, such as rubber hose and various forms of metal coatings, such as Bonderite and Permlite. These were subjected to the action of 6 different sprays as well as tap water. Results are given in table form.—INCO. 4851

## 6.6 Non-Metallic Materials

### 6.6.5, 8.1.2

**Corrosion-Resistant Flooring Materials.** *Brit. Indust. Finishing*, 3, No. 31, 490-492, 494-497 (1951).

A survey of flooring materials designed for use under a) severely corrosive conditions such as galvanizing and pickling shops, and b) mildly corrosive conditions. Brick-and-tile construction is recommended for a) and the merits of hydraulic, silicate, rubber latex/hydraulic sulfur, synthetic resin, and bituminous cements are compared. The available continuous type and resin bound tile floorings suitable for b) are considered.—MA.

### 6.6.5, 7.5.5, 4.3.2

**Corrosion-Proof Cements Extend Pickling Tank Life.** C. F. SAUERREISEN. Sauerreisen Cements Co. *Iron Age*, 168, No. 8, 66-68 (1951) Aug. 23.

Life of steel mill pickling tanks and other equipment subject to acids and al-

kalis is extended and maintenance costs are cut where corrosion proof cements are used. Carbon brick is recommended for handling strong alkalis. Hydrofluoric acid or hydroiodic acid and nitric acid mixtures. Impervious membranes are used to protect the outer shell from attack by seepage and over-come effects of expansion and contraction caused by temperature changes. These membranes may be of rubber, lead, or of asphalt or bitumastic compositions. Applications of these cements are discussed. A selection chart for corrosion-proof cements is given.—INCO. 4944

### 6.6.7, 5.11

**Neoprene Applications in Engineering Design.** R. W. MALCOLMSON. E. I. Du Pont De Nemours & Co., Inc. *Mechanical Eng.*, 73, No. 8, 627-632, 643 (1951) Aug.

Neoprenes are made in two forms;

so-called "dry" polymers which bear a close resemblance to crude rubber, and water dispersions, known as neoprene latices, which are indistinguishable from natural-rubber latex on casual examination. The several types of neoprene and neoprene latex all possess to a high degree the outstanding properties for which neoprene is noted. These include resistance to deterioration by oils, solvents, and chemicals, sunlight and weathering, oxidation, heat, flexing, abrasion, and flame. However, each type has its own special characteristics which contribute to its usefulness in specific applications. This paper discusses some of the principal properties of neoprene compositions and describes some of their engineering applications. In this discussion, the values reported are typical of those obtainable in commercial practice.

## TK-2 LINING PROTECTS 7 MILLION FEET OF OIL COUNTRY PIPE AGAINST PARAFFIN or CORROSION

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TK-2 ends paraffin accumulation in producing wells. It resists corrosion in wells where ordinary pipe is damaged by gas condensate or sour crude. It is especially practical for wells on packer, high pressure wells, offshore or isolated wells, and for wells with storm chokes. In process and chemical plants it stands up under severe, corrosive conditions.

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Case histories show that initial cost is saved many times over when pipe is lined with TK-2. Save pipe, save down-time, save replacement labor.

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Unless otherwise specified, the characteristics described were obtained with the general-purpose types of neoprene. This discussion is divided into two phases as follows: Basic Properties—These include all the characteristics such as hardness, tensile strength, compression set, and resilience which govern its ability to perform its function upon being placed in service. Resistance to Deterioration—This covers measurements of the extent to which original properties are retained during exposure to deteriorating influences such as oil, sunlight and weathering, oxidation, and heat.—TDD. 4874

#### 6.6.8, 4.3.7

**Materials of Construction Versus Hydrogen Peroxide. Silicones.** J. A. McHARDY AND L. VAN VOLKINBURG. *Chem. Eng.*, 58, No. 10, 270 (1951).

Data on the resistance of silicones to hydrogen peroxide are limited almost entirely to aqueous 3% solutions. Isolated examples of use at higher concentrations are known. From the limited data available, the silicones show generally good resistance to the dilute aqueous reagent. Concentrated hydrogen peroxide forms an explosive mixture with almost all organic materials. Because all of the silicones contain organic radicals, their use in contact with concentrated hydrogen peroxide should be preceded by careful testing in actual service.—RPI. 4802

#### 6.6.11, 5.4.5, 2.3.6

**Microscopic Studies of Polished Wood Surfaces.** H. NIESEN. *Deutsche Farben-Z.*, 5, No. 4, 117-119 (1951).

The investigation of checking on lac-

quered wood veneers is discussed. The distinction between lacquer checks and checks in the veneers is illustrated by photomicrographs.—RPI 4803

#### 6.6.8, 5.4.5, 7.2

**Kel-F Applications in Corrosive Systems.** L. C. RUBIN AND W. O. TEETERS. Paper presented at the Eighth Annual Conference, National Association of Corrosion Engineers, Galveston, Texas, March 10-14, 1952. *Corrosion*, 9, No. 3, 100-102 (1953) Mar.

A series of exceptionally heat-stable thermoplastic fluorochlorocarbons derived from chlorotrifluoroethylene and commercially available under the trade name Kel-F are highly resistant to a large number of chemicals. Their properties make them particularly attractive for use as thermoplastic protective coatings and in the form of molded separators. Some aspects of the development work and results obtained in solving corrosion problems are presented in this article.

The use of diaphragms of this material in Saunders' type valves has solved many difficult commercial operating and corrosion problems. Suitably designed "O" rings and gaskets have solved gasketing problems in some highly corrosive systems. Other similar applications are being studied.

The application of these coatings to protect metal surfaces exposed to corrosive systems is being studied via dispersions of finely divided plastic in a volatile vehicle. Preliminary data on the vapor permeability of the films prepared from dispersion indicate it to be superior to most other plastic films tested.

The performance of the coatings is dependent to a large extent on the mo-

lecular weight of the polymer. Molecular degradation of the polymer during the fusion operation and subsequent heat aging is influenced by various metals; in some cases excessive degradation has resulted.

The coatings have been tested in the laboratory with a large variety of corrosive materials and numerous field tests are under way.

### 6.7 Duplex Materials

#### 6.7.2, 3.5.9

**High-Temperature Bodies Derived from Mixtures of MgO-TiN-NiO.** L. D. HOWER, JR., J. W. LONDEREE, JR., AND H. F. G. UELTZ. *J. Am. Ceramic Soc.*, 34, No. 10, 309-313 (1951) Oct.

The mixtures are sintered in a protective argon atmosphere, nickel monoxide being reduced to nickel. The titanium nitride promotes a bond between the nickel and magnesium oxide. The use of nickel monoxide instead of nickel powder results in a superior distribution of metal in the product. Transverse strength and resistance to thermal shock were determined at temperatures up to 1316° C., before and after exposure to a hot oxidizing atmosphere.—BNF.

#### 6.7.2, 3.5.9

**Study of Metal-Ceramic Interactions at Elevated Temperatures.** Massachusetts Inst. of Tech. F. H. NORTON AND W. D. KINGERY, et al. Apr. 1, 1952.

A review of the literature pertaining to carbide, nitride, and sulfide reactions with metals has been completed. Samples of nitrides and carbides have been prepared for use in reaction and surface tension studies. Surface tension and wettability data for iron, nickel, and silicon on ceramic oxides have been reviewed and the results are summarized. Additional improvements and tests of a microscopic furnace for sintering studies have been completed and spherical particles of aluminum and zirconia prepared. (auth.)—NSA. 4883

#### 6.7.2, 3.5.9

**New Chromium Carbides Have High Temperature and High Corrosion Resistance.** *Materials & Methods*, 34, No. 6, 69 (1951) Dec.

A new member of the group of cemented carbide materials—chromium carbide—has recently been made available in limited quantity. Expansion of production facilities has already begun. This article briefly describes the important features of the chromium carbide series, and lists expected applications.—TDD. 4904

#### 6.7.2, 3.5.9

**Final Report on Development of Metal-Ceramic Compositions Suitable for Service at Elevated Temperatures.** W. D. KINGERY, G. ECONOMOS, M. HEMENIK, JR., AND M. BERG. Massachusetts Inst. of Tech. April 30, 1951. 54 p.

Data are reported from fundamental investigations of the properties of metal-ceramic compositions suitable for service at elevated temperatures. Metals investigated were silicon, beryllium, nickel, and iron. Ceramic materials employed were aluminum oxide, zirconium dioxide, magnesium oxide, beryllium oxide, beryllium carbide, titanium dioxide, and graphite. Data on surface tension, wettability, interface reactions, and sintering are included.—NSA. 4737

**THICK, TOUGH  
COATING for  
STRUCTURAL STEEL—  
TANK LININGS—  
Resists...**



CORROSIVE	CONCENTRATION	TEMPERATURE
Hydrochloric Acid	Up to 37%	Up to 100°F.
	Up to 25%	Up to 140°F.
	Up to 15%	Up to 185°F.
Sulfuric Acid	Up to 78%	Up to 100°F.
	Up to 65%	Up to 122°F.
	Up to 50%	Up to 185°F.
Phosphoric Acid	Up to 85%	Up to 100°F.
	Up to 50%	Up to 185°F.

### A High Solids Neoprene Base Coating Which Drastically Reduces Labor of Application

**On the Inside of Tanks:** Apply a 1/16" corrosion-resisting lining of low cost Neoprene 100 in 4-7 brush coats instead of the 10-20 required with ordinary neoprene linings. Spraying Neoprene 100 provides dry films of 5-10 mils per coat on vertical surfaces. Coatings cure at room temperature. Material and labor cost for a 1/16" tank lining including sandblasting is approximately \$1.10 per square foot on steel or concrete. Neoprene 100 has a long pot life. Ready-to-use mixtures remain brushable 2-3 days.

**On the Outsides of Tanks and on Structural Steel:** Inexpensive, easy-to-use primers are available for applying Neoprene 100 to rusty or damp steel or over old paints. No expensive surface preparation is necessary.

See Bulletin 700 for details.



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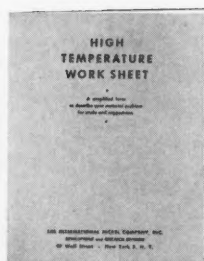


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## 6.7.2, 8.9.1, 7.1, 3.5.9

**Cermets May Answer Jet Designers' Prayers.** W. J. KOSHUBA AND J. A. STAVROPOULAKIS. *Gen. Elec. Co. Iron Age*, 168, No. 22/23; 77-80, 154-158 (1951) No. 29, Dec. 6.

Pressed-and-sintered ceramic mixtures are still in the experimental stage, but in jet turbines it already looks like they will replace some strategic alloys. Hydrostatic and hot pressing seem the best forming methods. Carbides, oxides, alumina, chromium, titanium, beryllium have been investigated. In solid solution cermets, there is evidence of the solution of nickel, cobalt and iron in titanium carbide in the range of 3000°F. Nickel exhibits the highest solubility and iron the least. One disadvantage of extremely fine metallic powders is their tendency to oxidize rapidly; even iron and nickel tend to be highly pyrophoric. Exploratory studies of titanium carbide base metal-ceramic report combinations of titanium carbide with cobalt, nickel, tantalum carbide and cobalt. While wear resistance, general high-temperature behavior and strength-to-weight ratio is good, cermets are less shock resistant and less ductile. These new materials are likely to see service in rockets, thermo-couple protection tubes, induction heating coils and electronic cathodes. Tables, graphs and 15 references are included.—INCO. 4739

## 6.7.3, 4.3.1, 4.4.1

**Corrosion Resistance of Typical Laminated Metals.** *Product Eng.*, 22, No. 5, 211 (1951) May.

Chart gives corrosion resistance to sulfuric acid, nitric acid, hydrochloric acid, acetic acid, sodium hydroxide, ammonia, sulfur dioxide, sulfur, fruit juices, phosphoric acid, ink, and sea water of platinum, gold, lead, silver, nickel, Monel, copper, nickel silver, bronze, and 18-8 stainless steel.—INCO. 4882

## 7. EQUIPMENT

## 7.1 Engines, Bearings, and Turbines

## 7.1, 3.5.8

**Distortion and Failure of Steam Turbines and Their Prevention.** (In German). ERNST POHL. *Stahl und Eisen*, 71, 1375-1379 (1951) Dec. 6.

Discusses warpage of shafts and its elimination; cracks extending from the age-hardened zone and the rim caused by prevention of expansion; and fatigue failure of moving blades caused by vibration, notches, and stress corrosion. Methods of alleviation are discussed. Illustrations show various failed pieces.—BLR. 4896

## 7.1, 3.5.9

**Heat Resistant Materials: Refractory Materials in the Construction of Jet Engines.** (In French). Y. LETORT. *Métaux: Corrosion Industries*, 26, No. 310, 250-255 (1951) June.

Describes the various components submitted to high temperatures, together with other localized conditions, such as vibration, corrosion, etc. Accordingly, special additional properties which a refractory material should possess are discussed. Individual refractory materials with melting point, and, where applicable, boiling point or approximate dissociation point, are then listed under the headings: high temperature metals; refractory oxides; spinels; silicates and

zirconates; porcelains; metallic carbides; nitrides; sulphides and borides; glasses; cermets; enamels.—BNF. 4917

## 7.1, 3.5.9, 4.3.3

**Progress Report on the Leading U. S. Maker.** *Oil Engine and Gas Turbine*, 18, 395-398 (1951) April.

Early General Electric Company (Schenectady) interest in gas turbines and developments in recent years. Note on overcoming vanadium attack in original 4800 h.p. single-shaft engines, by changing nozzle blade material and reducing temperature peaks in gas stream.—INCO. 4815

## 7.2 Valves, Pipes and Meters

## 7.2, 5.4.3, 8.1.4

**Protection for Sewer Pipes.** *Modern Plastics*, 29, 102-103 (1952) Jan.

Describes and illustrates the use of molded vinyl sheet for the successful protection of concrete sewer pipe against H<sub>2</sub>S. It is unaffected by bacteria, acids, alkalis, humidity, oxidation, and aging.—BLR.

## 7.2, 6.5, 4.6.1, 3.3.5

**Review of Current Investigation No. 8 (of Institution of Water Engineers). Research Group Report (f) Waterworks Fittings (Ball-Valve Seats).** *Institution of Water Engineers Research Group. J. Inst. Water Engrs.*, 5, No. 7, 700-718 (1951) Nov.

Tests on high tensile brass, aluminum bronze, phosphor bronze, nickel silver, Monel and 60/40 brass. Monel metal proved the most resistant as valve seating in all but 5 of 17 series of tests in both unchlorinated and chlorinated waters. It is concluded that in respect of resistance to corrosion-erosion this material is the most satisfactory for replaceable seating for ball valves of BS. 1212 type in all waters apart from those possessing very unusual characteristics, such as very high carbon dioxide content. Phosphor-bronze was next in order of merit to Monel.—BNF.

## 7.2, 6.2.5, 3.5.9

**High Temperature Properties of Stainless Steel Tubing.** *Materials & Methods*, 34, 113 (1951) Sept.

Presents tabular data on mechanical and physical properties of 7 types. Includes temperature of inception of embrittling grain growth, resistance to intergranular carbide precipitation, and safe temperatures for use in oxidizing atmospheres.—BLR. 4838

## 7.2, 6.6.5, 4.3.2, 4.3.6, 4.6.5

**Corrosion of Cement-Bonded Sewer Pipes.** H. F. LUDWIG AND R. G. LUDWIG. *Water and Sewage Works*, 98, 404-407 (1951).

Three types of concrete and two types of concrete-asbestos pipe were exposed to attack by distilled water, dilute sulfuric acid, and a solution of sodium sulfate. The rate of loss of acidity was measured in the case of acid solutions containing initially from 10 to 25,000 p.p.m. of sulfuric acid. In the case of the tests with distilled water and 1% sodium sulfate the rate of gain of hardness (calcium + magnesium) in the recirculated solution was measured by the versenate method. The cement bond of both concrete and cement-asbestos pipe was attacked and deteriorated in all cases. 4778

## 7.2, 6.6.8

**Phenolic-Butadiene-Acrylonitrile Polymers for Pipe and Pipe Fittings.** R. MCFARLAND. *Corrosion*, 9, No. 4, 1 (News Section) (1953) April.

Characteristics of the phenolic-butadiene-acrylonitrile polymers are listed. Pipe and fittings of the material can be machined and joined like standard metal pipe. Valve bodies of the polymer are being made from ½ to 2 inches in size. Non-toxic, the material is useful for handling food products. A list of the reagents to which the polymer is resistant is given. 4800

## 7.3 Pumps, Compressors Propellers, and Impellers

## 7.3, 3.5.1, 8.10.3

**Wear and Damage to Underground Pumps. II.** (In Japanese). ICHIRO ONUMA. *J. Mechanical Laboratory*, 5, 252-261 (1951) Oct.

204 pumps located in a Japanese coal mine were inspected. Causes of breakdown are allocated percentage-wise to the following causes: wear, corrosion, seizure, and others, for the various parts. Data are charted and tabulated; diagrams show the parts involved.—MA. 4818

## 7.3, 6.3.6, 3.2.2, 2.3.7

**Season Cracking of Manganese-Brass Propellers.** Y. KANEDA. Paper before 1st World Metallurgical Congress, Detroit, Oct. 1951. *Proc. 1st. World Metallurgical Congr.*, ASM, 1951, 637-644.

Tests for season cracking in manganese-brass propellers are studied. Ammonia tests are sensitive to residual stresses but insensitive to microstructure. Acidified ferric chloride solutions are sensitive to both residual stresses and microstructure. The latter test gives cracks that are similar to those found in service, whereas the ammonia test does not. A summary of service failures is described in terms of residual stresses and microstructure. Tables and photomicrographs are included.—INCO. 4730

## 7.5 Containers

## 7.5.2, 6.4.2, 8.3.5

**The Aluminum Food Can in Europe.** *Modern Metals*, 8, No. 2, 26-28, 30-32 (1952) Mar.

Many countries have successfully used aluminum for canning. Production of sheet and the manufacture of cans are considered. Pure aluminum (2S) and stronger alloys can be used. Deep drawn containers developed by Jakob Keller are made from aluminum circles in one operation. Aluminum cans give good shelf life and do not disturb the taste, appearance and nutritive value of the food. For milk products and fish, the aluminum should be anodized. It can be anodized or lacquered for vegetables. Handling and treating of aluminum cans are the same as for tin cans. An overpressure retort was designed for the processing procedure. The reasons why aluminum can be used for canning are given. Illustrations.—INCO.

## 7.5.5, 3.6.6, 8.9.5

**Scale vs. Bare Steel Potential Differences May Explain Unusual Tank Vessel Corrosion.** *Corrosion*, 9, No. 5, 1 (News Section) (1953) May.

Severe corrosion of piping in new tank



vessels is attributed in part to the action of high temperature, high pressure salt water used for cleaning the tanks. The streams of water removed the protective covering of corrosion products on the pipes on areas oriented to the cleaning nozzles. The resulting bare areas suffered severe pitting as a result of the difference in potential between bare steel and steel scale. The worst attacks occurred in vessels ballasted with sea water, indicating the neither the cargo per se nor the cleaning per se was directly responsible. 4897

#### 5.5, 5.2.3, 5.2.2

**Cathodic Protection of Tank Bottoms.** M. E. PARKER, *Oil & Gas J.*, 49, No. 52, 131 (1951) May 3.

Underside of steel storage tanks are subject to corrosion by the soil. Protection by rectifiers and ground beds may be used where the soil resistivity is high, about 1,500 ohm-cm., and where total current requirement is large. Magnesium anodes may be preferred for isolated single tanks, even in high-resistivity soil; where the soil resistivity is low; and where the fire hazard is great, provided adequate precautions are observed. 4790

#### 7.7 Electrical—Telephone and Radio

#### 17.6.4.2, 5.4.5

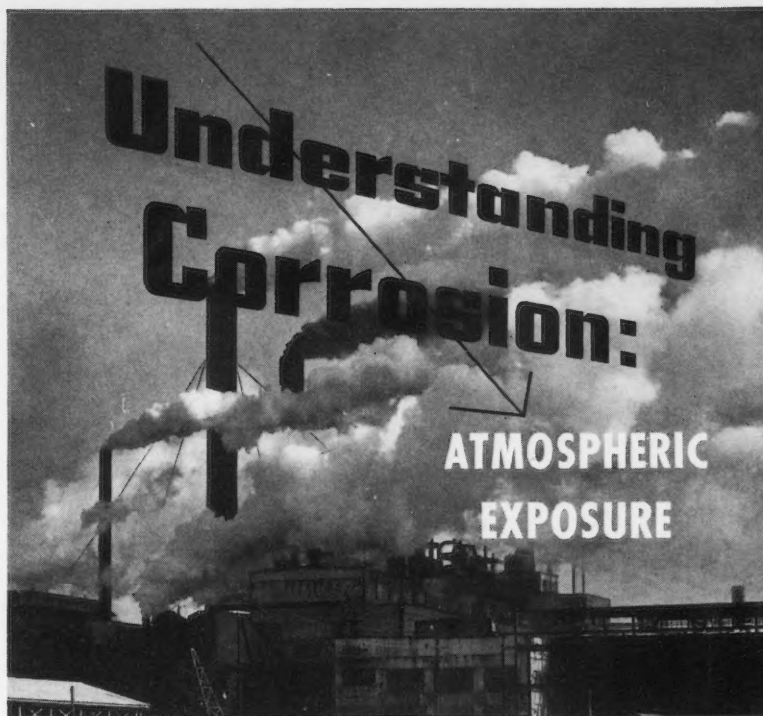
**Aluminum Alloy Electrical Conduits and Fittings.** *Electrical Times* (England), 120, 885 (1951) Nov.; *Light Metals Bull.* (England), 14, No. 1, 30 (1952) Jan. 4.

Grades of electrical conduit and fittings in aluminum alloys should bear permanent distinguishing marks, to enable the man on the site to make a proper choice. Great care should be taken in the installation and selection of the most suitable grade for given conditions. For saline, smoke and chemical atmospheres the aluminum should have been chemically treated to ensure good paint adhesion, and at least two coats of zinc chromate base paint with one or more finishing coats of good quality paint are needed. For contact with damp concrete, plasters and Portland cement mixtures a covering of bitumen applied hot, or two coats of bitumastic paint, is advised. For contact with acid woods, such as oak and teak in damp situations, the same protection as for saline atmospheres should be provided, or insulation by pressboards or felt. Account should also be taken of the difference in mechanical properties of steel and aluminum conduit and fittings.—ALL.

#### 17, 2.3.5

**Electrolytic Corrosion Tests in Pressure-Sensitive Electrical Tapes.** C. W. REMMELS, R. J. PRIEPKE, and L. D. FALCON, *Elec. Mfg.*, 47, No. 4, 129-131, 248, 250, 252, 254 (1951) April.

Electrolytic corrosiveness of pressure-sensitive tapes was measured by the corrosion current method, the cut-edge test and the contact method. The three methods agree roughly in classifying tapes. It is demonstrated in this investigation that the corrosion current method is the best means of measuring electrolytic corrosiveness. This test is easy to carry out, and the results are reproducible and correlate closely with those obtained by the more complex cut-edge technique. The usual bare-wire test method appears to be the least satis-



The extent to which metal will corrode in atmosphere—or even whether it will corrode at all to any appreciable degree—is determined primarily by the moisture content of air. While deterioration at normal temperatures and humidities of less than 35% is so slow as to be almost negligible, the rate accelerates rapidly beyond a critical point of approximately 65%. This activity is intensified when such contaminants as hydrogen sulfide or sulfur dioxide are absorbed from industrial atmospheres. Impingement of solids, which tends to hold this acid film in contact with metal, localizes and further advances corrosive attack.

When exposure to atmosphere includes also exposure to sunlight and to the variables of weather, the situation becomes more complex. Such factors as the composition of metal and of the protective rust film that forms upon it, the length of time surfaces are wet, the extent

to which they retain moisture, and whether they may be bared intermittently by heavy rainfall are influential in determining metal life.

An understanding of the mechanism of corrosion in all of its varied phases is an obvious requisite to prescribing methods of control. Thirty-five years' study and evaluation of industrial corrosion problems and the formulation of protective coatings to meet them has taught us something about corrosion and the ways in which it may be checked successfully.

We are ready to share that knowledge with you in an analysis of any metal-maintenance problem you feel requires the *different* approach of considered engineering judgment . . . to give you a recommendation you can be sure is technically correct and practically workable—for quality protective surfacing that is right for you because it is individually job-selected to meet your service specifications.



160-1

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factory of the three test methods examined. Illustrations, tables of corrosiveness and ratios of tensile losses of the positive wires and graphs of results are given.—INCO.

#### 7.7, 5.11, 6.3.8

**Bell System Cable Sheath Problems and Designs.** F. W. HORN AND R. B. RAMSEY. (Bell Telephone Labs.) Paper before AIEE Fall Gen. Mtg., Cleveland, Oct. 22-26, 1951. *Elec. Eng.*, 70, No. 12, 1070-1075 (1951) Dec.

Mechanical, electrical and corrosion requirements of cable sheaths are described. Duct and buried cables are more subject to corrosion than aerial ones. Normal atmospheric conditions keep aerial cables dry. Plain lead, alpth, stalpeth and lepeth sheath designs are discussed. Lead is satisfactory in dry surroundings but susceptible to corrosion in a wet environment if stray electric currents or corrosive soil conditions exist. In fatigue the alpth sheath is better than lead and its polyethylene jacket is a corrosion resistant covering. Cable sheaths may be jute protected, polyethylene jacketed, steel tape armored, light wire armored, or single and double wire armored, depending on use.—INCO.

### 8. INDUSTRIES

#### 8.1 Group 1

##### 8.1.2, 5.4.5

**Corrosion-Resistant Paints and Plastic Coatings from Coal Tar in the Building Industry.** K. MEYER. *Bitumen, Teere, Asphalte, Peche*, 2, Nos. 7/8, 165-169, 204-207 (1951).

A review of the composition, properties (especially sensitivity to light and water) and applications of pitches and

treated pitch from coal tar in paint, roof coverings, floor compositions, etc. 35 references.—RPI. 4919

#### 8.1.4, 6.5, 7.2, 7.3

**Review of Current Investigations No. 8-Research Group. Report: Waterworks Fittings.** J. Inst. Water Engrs., 5, 700-718 (1951) Nov.

Test methods for assessing behavior of ball-valves and that of materials of construction of valve seats are given. Alloys involved are high tensile brass, aluminum bronze, phosphor bronze, nickel silver (19.6 nickel, 64.3 copper, 5.1 tin, 4.7 lead, zinc balance), Monel and 60/40 brass. Chlorinated and unchlorinated waters are used at different test locations. Nickel silver results varied from place to place and from condition to condition. Of all alloys tested, Monel proved most resistant in all but 5 of 17 series of tests in both chlorinated and unchlorinated waters. It is concluded that for valve seats in all waters apart from those possessing very unusual characteristics, such as very high carbon dioxide content, Monel is most satisfactory material from point of view of corrosion-erosion. Section of the paper is devoted to properties of Monel. Table shows relative costs of Monel, stainless steel and the other alloys tested. Monel is most expensive, but cost is unimportant compared with longer life of valve seat and saving of waste and maintenance.—INCO. 4729

#### 8.2 Group 2

##### 8.2.2, 3.5.8

**Causes of Breakdown in Steam Plant.** *Proc. Inst. Mech. Engrs.* (London), 164, No. 2, 129-136 (1951).

Presents a discussion by various speakers on the above. Causes such as mechan-

ical failure of metals, stress corrosion, reliance on automatic controls and vibrations of parts are discussed in detail. Illustrations and diagrams.—BLR.

#### 8.3 Group 3

##### 8.3.4, 8.3.2, 6.2.4, 6.4.2

**Modern-Winemaking.** W. O. HULL, W. E. KITE AND R. C. AUERBACH. (Roma Wine Co.) *Ind. & Eng. Chem.*, 43, No. 10, 2180-2192 (1951) Oct.

Stainless steel of Types 302, 304, 316 and 321 find wide application in the winemaking industry in the crushing, fermentation, pasteurization and bottling processes. Cast alloy steel containing 4-6 chromium is used in screw presses while filter presses are constructed of aluminum alloy. 19 literature references and 18 references to processing equipment are included.—INCO.

##### 8.3.3, 6.4.1

**Anticorodal Milk Churns.** *Metalen* (Holland), 6, 138 (1951). Apr. 30; *Light Metals Bull.* (England), 13, No. 14, 507 (1951) July 6.

In August, 1951, two firms in Groningen and Gorredijk (Holland) will begin the joint production under license of the well-known Anticorodal milk churns. These churns are made seamless, and consist of the soft annealed alloy Anticorodal (of the aluminum-magnesium-silicon type). After fabrication they undergo heat treatment which considerably increases their mechanical strength. In order to augment their natural resistance to corrosion, they are then anodized.—ALL. 4854

##### 8.3.5, 6.5

**Chemical Engineering in the Meat-Packing Industry.** M. D. SANDERS, A. W. DEVOUT, P. BRADFORD, AND W. F. BOLLENS. Paper before Amer. Inst. of Chem., Eng., Minneapolis Mtg., 1951. *Chemical Eng. Progress*, 47, No. 9, 443-448 (1951) Sept.

Describes the operations employed in the preparation of the by-products of the meat packing industry in the production of soap, glycerine, lard, industrial fats, fat derivatives, glue, gelatin, and livestock feeds. There is also a discussion of the suitability of lead, nickel, copper, Inconel, stainless steel and carbon steel for the corrosive resistant equipment used in these various operations.—INCO. 4941

##### 8.3.6, 5.4.5

**Corrosion Prevention in Sugar Industry.** K. R. MCNAUGHT. *Proc. Queensland Soc. Sugar Cane Technol.*, 17th Conf. 83-88 (1950).

The effective protection of metal surfaces against corrosion in sugar mills where operations are seasonal is discussed. The advantages of petroleum base preventative materials are stated. Oil-type, grease-type, and solvent or "cut-back" type are considered in relation to special applications. A solvent type which dries to a hard, durable film and a type which dries to a soft film probably satisfy all the demands in a sugar mill.—INCO. 4805

#### 8.4 Group 4

##### 8.4.2, 4.3.4, 6.2.3

**H<sub>2</sub>S and CO<sub>2</sub> Corrosion of Carbon Steel in Natural-Gas Processing Plants.**

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D. E. McFADDIN. Union Oil Co. of Calif. Paper before C.N.G.A., 26th Ann. Fall Mtg., Los Angeles, 1951. *Oil Gas J.*, 50, No. 32, 97-98 (1951) Dec. 13.

Study of case history undertaken by Union Oil Co. at its Santa Maria Valley operation concludes that corrosion due to carbon dioxide is no problem provided that no water is present. Steel, copper, brass and nickel give satisfactory service. Hydrogen sulfide attacks steel and most other metals in general use. Suggestions are given for mitigating corrosion. Chemical reactions are tabulated which represent the basic changes taking place during carbon dioxide and hydrogen sulfide corrosion.—INCO. 4821

## 8.5 Group 5

### 8.5.3, 6.2.5, 6.6.6, 7.6.1, 7.5.5

**Magnesia-Base Sulfite Pulping.** W. Q. HULL, R. E. BAKER (Weyerhaeuser Timber Co.) AND C. E. ROGERS (Babcock & Wilcox Co.) *Ind. & Eng. Chem.*, 43, No. 11, 2424-2435 (1951) Nov.

Manufacture of pulp by magnesia-base pulping is summarized. Corrosive nature of the acid cooking liquor requires stainless steel in all equipment where contact with metal occurs. Type 316 stainless steel is used in all tubing and pipe that convey the liquid throughout the cooking and recovery plants. Type 316 is also used in all pumps and processing equipment where metal contact is made. Acid-resisting brick and tile are used as linings for digesters, dump tanks, and adsorption and acid-fortifying towers, which are constructed of steel plate and/or concrete. Tables and diagrams are included. 13 references.—INCO.

### 8.5.3, 6.2.5, 7.6.6

**Stainless Steel Lining of a Pulp Mill Digester.** S. C. JOHNSON AND N. J. GIBSON. Paper before Australian Pulp and Paper Ind. Tech. Assoc., 4th Gen. Conf. *Paper Trade J.*, 133, No. 11, 20, 22-24, 26-27 (1951) Sept. 14.

Digesters of mild steel used for sulphate digestion of eucalypts were showing serious corrosion so that their life would have been 8-10 years. One of them, indirectly heated and with a capacity of 1350 cubic feet was lined, while in place and after several years' service, with austenitic stainless steel (Weldanka). The major part of the internal surface was lined with 12 gauge cold-rolled annealed and pickled metal in form of strips four inches wide. The first two welding runs joined the strip to the shell and the 3rd run filled the gap and covered the diluted weld-metal of the first 2 runs. The strainer screen plates and liquor inlet pipe and spray were made of the same grades of stainless steel. After 15 months' service the lining was in excellent condition.—INCO.

### 8.5.3, 6.3.6, 3.1

**Corrosion of Fourdrinier Wire Cloth.** A. G. HOSE. (The Lindsay Wire Weaving Co.) Paper before the Southern and Southeastern Divisions of the American Pulp and Paper Mill Sup'ts Assoc., Joint Fall Mtg., Jacksonville, Fla. *Paper Trade J.*, 133, No. 21, 22-23 (1951) Nov. 23.

Discussion of the forms and problems of corrosion found in used wire cloths. Some of the forms discussed are straight chemical, electrolytic (galvanic, intergranular, pitting and corrosion-erosion) corrosion, and corrosion fatigue.—INCO.

### 8.5.3, 6.3.6, 3.1

**Corrosion-Resistant Metals for the Pulp and Paper Industry.** D. L. HORGAN. Paper prepared for Pulp & Paper Course, Univ. of Maine. *Paper Trade J.*, 133, Nos. 14, 15, 24+; 20+ (1951) Oct. 5, Oct. 12.

Various types of corrosion encountered in pulp and paper mills include oxidation, galvanic attack, pitting, intergranular, stress, crevice, erosion, and cavitation. Properties of various corrosion-resistant metals such as nickel-base metals including nickel, Monel and Inconel, stainless steels of both the straight chromium types and the nickel-chromium types are discussed. Plate, sheet and strip forms are dealt with at some length. Specific applications in pulp and paper processing are given in outline form, listing only those items where corrosion-resistant metals have been used. Graphs and photomicrographs are included.—INCO.

### 8.5.2, 6.6.6

**Stack Condensation.** I. L. SAMPSON. *Glass Ind.*, 32, 457-458 (1951) Sept.

Outlines the problem of the above in melting borosilicate glass. The opinion of a technologist who has had broad experience in the use of borax glass is given.—BLR. 4938

### 8.5.3, 5.4.5

**Maintenance Through Protective Coating.** ROBERT H. MALOY. *Paper Mill News*, 74, 66, 68 (1951) Aug. 18.

Some of the places and conditions in paper and pulp mills where heavy coatings can prevent corrosion, and in some cases insulate vessels and retard condensation.—MR. 4836

### 8.5.3, 6.2.5

**Continuous Service With Low Maintenance Cost.** G. H. KLOUMAN. *Paper Mill News*, 74, 60-62 (1951) Aug. 18.

The proper care of stainless steel equipment. Paper-mill equipment that may be replaced by stainless, and types of stainless available.—MR. 4757

## 8.7 Group 7

### 8.7.1, 6.3.6

**The Cleaning and Preservation of Bronze Statues.** J. F. S. JACK. *Museums J.* (London), 50, No. 10, 231-236 (1951) Jan.

The original golden color of new, surface-finished bronze statues acquires a variety of less desirable shades ranging from pale green to dark brown or black and undergoes more or less severe corrosive attack during exposure to the weather. The composition of the bronze is of secondary importance compared with the type of atmosphere in which the statue is exposed.

In unpolluted, dry air the bronze will oxidize slowly and ultimately assume a dark brown color. In less dry, but not highly corrosive surroundings the well-known green of basic copper sulfate (patina) will be formed. Both the brown oxide film and the green patina film protect the underlying surface from further attack and are considered desirable rather than detrimental.

In heavily polluted atmospheres such as city air, bronze surfaces are subject to the action of industrial gases, smoke, soot, dust, and tar; these agents, in combination with rain water or other forms of humidity, form various copper salts on the bronze surface. If these salts are

water soluble, the attack can proceed continuously; flaking and ultimate perforation result. Rain and condensed humidity acting on deposits of dust, soot, and tar can also cause unsightly streaks and stains. The surface shape of a statue influences its weathering characteristics, since contaminated water can collect in crevices and becomes highly corrosive. The underneath surfaces generally show more serious corrosion than convex ones which are regularly subjected to the cleansing action of rain.

The best treatment for the preservation of bronze statues comprises the regular, frequent application of a film of oil or grease, such as bone oil or, preferably, lanolin, followed by wiping and polishing with a clean linen cloth or pad. This treatment promotes the formation of a desirable patina finish. The lanolin film absorbs water-containing corrosive agents and acts as a temporary barrier. The coating should be very thin to reduce the likelihood of dust or soot particles sticking to it, and should be renewed frequently to prevent the build-up of serious concentrations of corrosive material. Old films must be washed off completely before new films can be applied.

An alternative to lanolin is beeswax dissolved in turpentine, but this is not so easy to apply. A varnish such as cellulose acetate can also be used, but is more difficult to remove than is lanolin.

Detailed directions are included for treating new bronze statues, for periodic cleaning, and for treating neglected statues.

## 8.8 Group 8

### 8.8.1, 5.3.2, 6.3.11

**Silver in Chemical Plant.** *Metal Ind.* (London), 79, No. 11, 223 (1951) Sept. 14.

Silver, one of the most important corrosion-resistant metals, withstands the action of virtually all the organic acids and of many mineral acids and salts, can be used in the presence of halogens and their compounds and is unaffected by alkalis. Silver-lined mild steel equipment is now available to the British chemical industry combining high strength and corrosion resistance. Table is included.—INCO. 4843

### 8.8.1, 7.2, 6.5

**Piping Materials for Chemical Processes.** C. B. McLAUGHLIN, Tube Turns, Inc. *Heating, Piping Air Conditioning*, 23, No. 10, 85-94 (1951) Oct.

Detailed discussion of material and other piping requirements for chemical process use. The alloy steels, stainless steels, aluminum and aluminum alloys, nickel and nickel alloys including Monel and Inconel, and other construction materials such as Carpenter 20, aluminum bronze, Hastelloy alloys and nickel-plated carbon steels are given with their compositions and temperature service range. Piping engineer must consider pressure provisions, temperature conditions, corrosion, erosion and contamination in the piping itself or from catalytic action of the pipe metal upon the product conveyed, discoloration of product due to corrosion conditions and the weldability of the piping materials. Diagrams and tables are included.—INCO. 4806

### 8.8.3, 5.3.4, 5.9.4

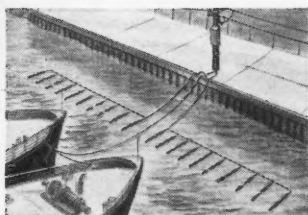
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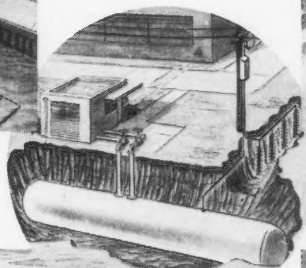
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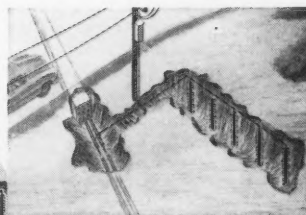
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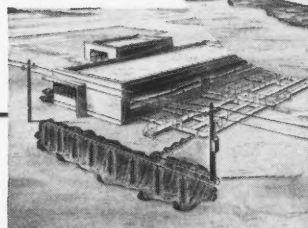
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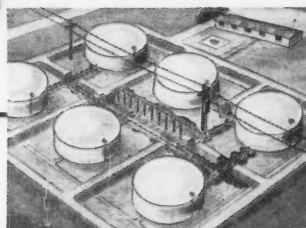
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## INDEX TO ADVERTISERS

Vol. 9      October, 1953      No. 10

Allen Cathodic Protection Co.	xiv
Amercoat Corporation	Inside Front Cover
American Chemical Paint Company	7
Arco Rubber Processors	
Div. Automotive Rubber Co., Inc.	23
Art Bookbinders	56
Bakelite Company, Div. Union	
Carbide & Carbon Corp.	24
Barrows Porcelain Enamel Co.	6
Bechtel Corp. & H. C. Price Co.	19
Brance-Krachy Co., Inc.	xiii
Calgon, Inc.	37
Carboline Company	52
Carpenter Alloy Tube Division, The	xi
Cathodic Protection Service	43
Chemical Corporation	30
Coast Paint & Lacquer Co.	33
Corrosion Directory	12, 13
Dampney Company, The	55
Dearborn Chemical Company	15
Delrac Corporation	32
Dow Chemical Company	ii
Dresser Industries, Inc.	vi
Duriron Company, Inc.	Inside Back Cover
Earl Paint Corporation	x
Electro Rust-Proofing Corp.	5
Federated Metals Division,	
American Smelting & Ref. Co.	4
Haveg Corporation	20
Hercules Powder Company	17
Illum Corp., The	16
Insul-Mastic Corporation of America	21
International Nickel Co., Inc.	vii, 53
Johns-Manville Sales Corp.	39
Koppers Company	31
Mayes Brothers, Inc.	36
Michigan Pipe Company	18
Monsanto Chemical Company	xii
National Association of	
Corrosion Engineers	vi, 13
National Carbon Company, Div.	
Union Carbide & Carbon Corp.	59
Nicolet Industries, Inc.	ix
Pipeline Anode Corporation	14
Pipe Line Service Corp.	35
Pittsburgh Coke & Chemical Co.	xv
Plastic Engineering & Sales Corp.	8
Polyken Industrial Tapes,	
Dept. of Bauer & Black	41
Positions Wanted and Available	13
Reilly Tar & Chemical Corp.	2
Republic Supply Company	i
Royston Laboratories, Inc.	
St. Joseph Lead Company	45
Saran Lined Pipe Company	47
Service Engineers, Inc.	42
Spring Packing Corporation	49
Stearns, D. E. Company	Back Cover
Tapecoat Company, The	11
Tretolite Company	57
Tube-Kote, Inc.	51
United Chromium, Inc.	61
United States Stoneware Company	9
Wilkinson Products Co.	44
Williamson, T. D., Inc.	62

plating Vats. O. P. KRAMER, *Metal*, 5, Nos. 7 and 8, 153-154 (1951).

Kramer stresses the importance of using the correct type of material for the construction of electroplating vats. A table is given which shows the recommended constructional materials and methods of heating the solution for most commercially deposited metals and types of electrolytes and for electrolytic degreasing and anodic oxidation.—MA.

4758

8.8.5, 1.5, 1.6

**Metal Finishing Guidebook-Directory: 20th Annual Edition, 1951, 568, Finishing Publications Inc., 11 West 42nd Street, New York 18, New York, \$2.50.**

Short articles on plant, surface preparation, plating baths (17 metals and alloys) and procedures, surface treatments (anodizing, coloring, etc.), control and analysis; tables of data; directory of U. S. manufacturers, trade names, consultants, etc. Much of the text is identical with that in previous editions: the new sections include: "Rectifiers," "Electrical Power Distribution in the Plating Room," "Avoiding Strong Currents in Plating Tanks," "Blast Cleaning," "Abrasives and Compounds for Polishing and Buffing," "Metal Cleaning," "Preparation of Various Base Metals for Plating," "Chemical Treatments for Zinc and Cadmium Plating"; deposition of acid copper, indium, iron, nickel, alkaline tin, tin-zinc, and cyanide zinc, analysis of tin-zinc and stannate tin baths; charts for calculating metal costs. The following sections have been revised: "Corrosion Resistant Tanks and Linings," "Automatic Controls for Plating Tanks," "Polishing and Buffing," "Identification of Plated Deposits"; while those on "Safety Equipment in the Plating Room" and "Black Nickel Plating" have been omitted.—BNF.

4845

8.8.5, 5.8.1, 5.5.1, 5.6.1

**Protecting Mechanical Parts from Corrosion, Mechanical World, 1951, 49-51, 61; Product Finishing, 4, No. 5, 92 (1951).**

A discussion of the methods of protecting corrodible surfaces during storage or transit. Most of the preventives function by providing a water-resistant barrier and include corrosion inhibitors. Application by dipping is suggested as giving the most complete and economical protection.—RPI.

4901

## 8.9 Group 9

8.9.2, 2.2.2, 1.7.2

**Miami Car Finish Test Station. Industrial Finishing (Brit.), 4, No. 41, 290, 292-293 (1951).**

Exposure testing at Miami and in Michigan is discussed. Weather recording at the Florida site, including sunlight and dew measurements, are described. The solar ultra-violet alone causes little damage to car finishes, but the combination of sunlight and dew causes most deterioration.—RPI.

8.9.3, 5.2.2, 5.2.3, 5.4.10

**It Pays to Control Corrosion. L. C. HILL. Kansas-Nebraska Natural Gas Co. Oil & Gas J., 50, No. 22, 287, 291 (1951) Oct. 4.**

Present day design requires all major transmission lines and distribution systems to be coated with a coal-tar enamel and glass wrap, fortified with cathodic protection using rectifiers and magne-

sium anodes. In the Platte Valley natural gas line, the high-carbon-steel pipe line was practically inoperative in 3-5 years without cathodic protection, and with cathodic protection the reconditioned line developed no leaks after 10-12 years.

8.9.3, 5.2.2, 5.2.3

**Pipe Line Corrosion. G. G. PORTCH. Elect. Times, 120, 4-10 (1951).**

Buried sacrificial anodes (e.g. 22-lb. magnesium blocks) connected to pipe can be used for cathodic protection, but applied direct current is preferable. Since protective current will vary with changes in soil resistance, constant current equipment is desirable. A brief illustrated description is given of such units as fitted every 5 to 10 miles along the 562-mile Kirkuk-Mediterranean pipeline. An oil-immersed transformer combined with selenium rectifier supplies 40 amperes at 50 volts. The ground bed is usually within 700 yards of the pipe, potential of which is maintained at -0.8 volts relative to the soil; to measure this accurately, a special copper/copper sulfate half-cell is required, an illustrated description of which is given in the original. General principles of corrosion and cathodic protection are outlined.—4890

8.9.3, 5.4.5

**Price's Somastic Division Has Coated Pipe for Many Major Lines. Oil and Gas J., 50, No. 24, 135-136 (1951) Oct. 18.**

History of the Somastic Division of H. C. Price Co. which is responsible for the application of Somastic to pipe for purposes of corrosion protection, and which has recently developed a process called Hevicote, for adding weight to pipe. Coating operation and composition of mixture are discussed.—4824

8.9.4, 5.11, 5.3.2

**Metal Spraying Railway Coaches. Metal Industry (London), 79, No. 8, 153 (1951) Aug. 24.**

An illustrated note on the 56 new railway coaches for the Indian Government Railways whose steelwork has been completely sprayed with zinc inside and out to a thickness of 0.004-0.005 inches. To make the coaches lighter than earlier models, their bodies were designed so that the stresses are distributed among all the members with the result that each individual component is stressed more highly than before. Failure by rusting would, therefore, be more serious and zinc spraying was chosen to protect the steel under the humid working conditions.—ZDA.

4844

8.9.4, 2.2.4, 6.2.4

**Corrosion of Steel Railway Sleepers-Final Report J. C. HUNSON. J. Iron Steel Inst., 169, Pt. 1, 13-16 (1951) Sept.**

The wastage, caused by rusting and abrasion, of copper-bearing steel sleepers is compared with that suffered by mild-steel sleepers in service tests lasting up to 14 years and made at 5 places on the British Railways (Western Region). Except in a railway tunnel, the copper-bearing steel was between 20 and 70% better than mild steel. Ordinary mild steel sleepers, weighing 150 lbs., should last for about 10-100 years, according to the locality, before they lose  $\frac{1}{4}$  of their original weight. Under normal circumstances the resistance of steel to rusting is adequate, but can be appreciably increased for sleepers laid in the open by using copper-bearing steel. Graphs and tables.—INCO.





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A producer of corrosive chemicals had several drums plastisol-lined for test. When research looked for the drums, they had disappeared. Later, they were found in the shipping department. They had been returned, inspected and re-shipped about 20 times. Regular lined drums had been good for only one to three trips.

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(2) They are resilient. While Unichrome Plastisol formulations can be modified to produce a coating in any range from soft to hard, the greatest number of applications seem to be in the elastic, rubbery range. In this state, Unichrome Plastisols can out-class rubbers on toughness, chemical inertness and economy for many applications. And unlike ordinary protective coatings, Unichrome Plastisols absorb abuse and impact without chipping.

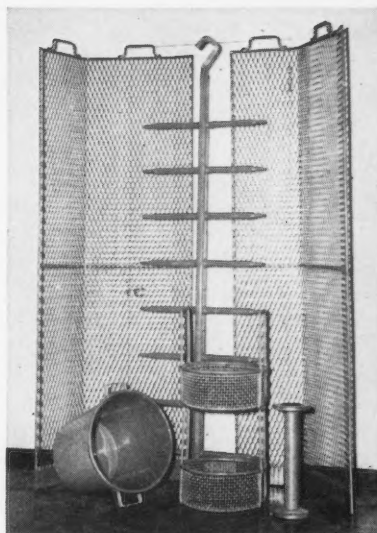
(3) Thick films can be produced. To guard against porosity in a coating and the possibility of accidental break-through, minimum film thicknesses are usually specified for protecting metals against strong corrosives. The thicker, the greater the protection. With ordinary coatings, this means applying many coats.

However, Unichrome Plastisol Compounds build up 3 mils to  $\frac{3}{16}$ " thicknesses with a single prime and a single top coat. They "cure" to stable form at 350° in only 20 minutes.

### TYPICAL RESULTS

Bleach reduction chambers of a noted chemical producer were coated with a Unichrome Plastisol Compound. This user reported that the coating gave 4 times longer service than even special alloy metals before requiring maintenance!

A processing plant replaced phenolic



Tank screens, plating rack, drum, dipping basket and flanged pipe that obtained extraordinary chemical resistance with Unichrome Plastisols

linings in equipment for spinning synthetic fibre with a Unichrome Plastisol Compound. By so doing, they ended build-up of hard sulfide deposits.

### ENDLESS OTHER USES

When battling corrosive liquids and fumes, plastisol coatings are so thick and tough they can be depended on not to break or wear through. That's why they're used to coat drain boards, to line pipe and fittings, to protect ventilating fans, ducts, solution agitators, processing baskets and the like.

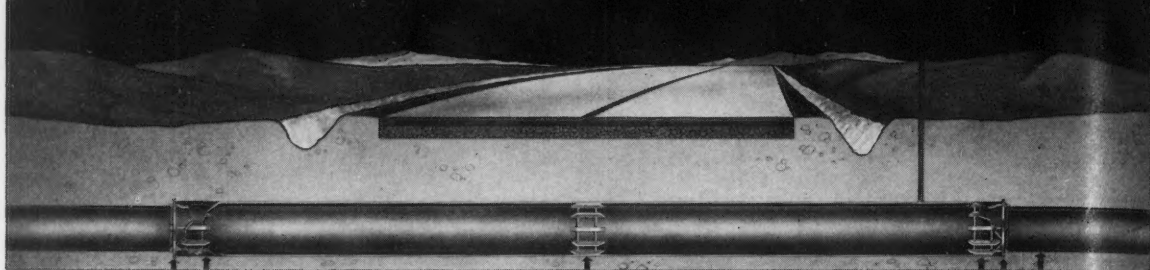
United Chromium's Technical Service department will be glad to give details on a specific plastisol to meet your problem. Write, giving details of the problem.

### UNITED CHROMIUM, INCORPORATED

100 East 42nd St., New York 17, N. Y.  
Detroit 20, Mich. • Waterbury 20, Conn.  
Chicago 4, Ill. • Los Angeles 13, Calif.

In Canada:  
United Chromium Limited, Toronto, Ont.

*A tested and proven design for efficient pipeline protection. . . . More than 18,000 crossings equipped since 1950. . . .*



## *Williamson* **CONCENTRIC-SUPPORT INSULATORS**

Provide low-cost, dependable protection for right-of-way crossings . . . Simple to install with a common wrench . . . Impervious to pipe coatings . . . Support blocks center pipe in casing, spacer blocks provide clearance through casing . . . Available for all combinations of pipe and casing diameters.

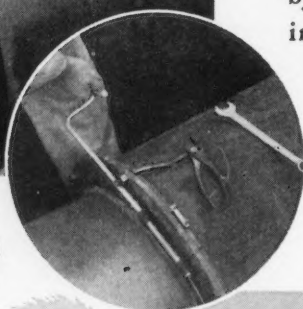


## **TYPE "L" WmSEAL CASING BUSHINGS**

Provide a water-tight seal even under the worst conditions of out-of-round casing . . . Unaffected by dirt, moisture or backfill during or after installation (no dope, adhesive or shield required) . . . Electrical insulation of pipe from casing provides economical cathodic protection.



*Easily installed with common hand tools.*



Write for Bulletin 249-A

**T.D. Williamson, Inc.**



**THE PIG WITH THE POKE  
CLEANS PIPE LINES**

P. O. BOX 4038

TULSA 9, OKLAHOMA

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Another leading manufacturer using

# DURCO

Chemical Service Valves

CHEMICALS



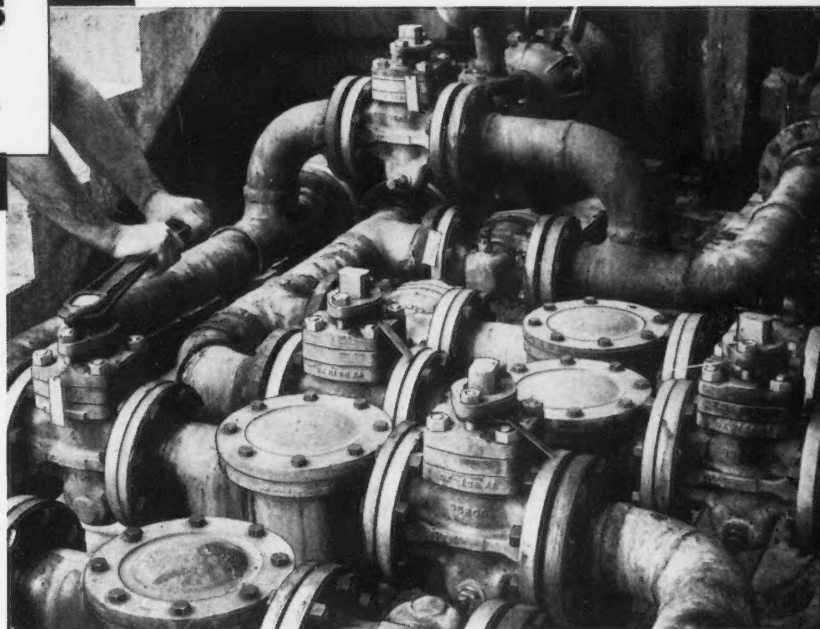
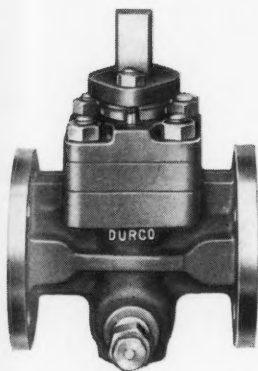
FOR INDUSTRY

**ROHM & HAAS  
COMPANY**

WASHINGTON SQUARE, PHILADELPHIA 5, PA.

*Representatives in principal foreign countries*

These Durco Type B Valves  
have been in sulfuric  
acid service at the Bristol, Pa.,  
plant for more than 3 years.



The Durco Type B Valves pictured here have been in service since 1950, handling corrosives ranging from dilute sulfuric acid at 150° F. to a mixture of concentrated sulfuric acid and organic materials at 200° F.

DURCO Type B Valves are heavy-duty chemical service plug valves, either top or bottom lubricated. They are available with flanged ends in sizes from 1" to 8", and with screwed ends from 1/2" to 2" in a wide range of DURCO corrosion resisting alloys including Durimet 20, Chlorimet 2, Chlorimet 3, 18-8-S-Mo, and others.

Rohm & Haas Company manufactures plastics, synthetic resins and chemicals for a wide variety of industries. Among the products manufactured at their Bristol plant is Plexiglas, their acrylic plastic. Plexiglas is widely used for outdoor signs, transparent aircraft enclosures, automobile stop and tail light lenses, nameplates for home appliances, and a host of other products.



Write for Bulletin V/2, and determine how DURCO can help solve your corrosion problems.



THE DURIRON COMPANY, INC., DAYTON 1, OHIO



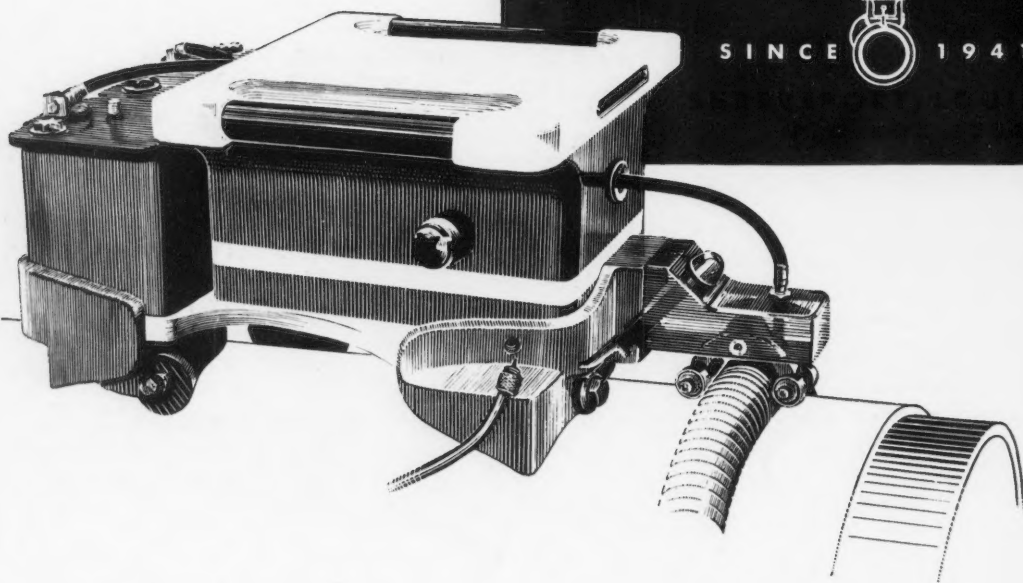
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One Purpose..*

...To supply the finest  
Holiday Detector  
Equipment available



**D. E. STEARNS**

SINCE  1941



BETTER COAT  
CONSERVE

2...

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